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THE GLOBAL ENVIRONMENTAL PROTECTION ACT OF 1988

JOINT HEARINGS

BEFORE THE

SUBCOMMITTEE ON HAZARDOUS WASTES AND TOXIC SUBSTANCES AND THE SUBCOMMITTEE ON ENVIRONMENTAL PROTECTION

OF THE

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS UNITED STATES SENATE

ONE HUNDREDTH CONGRESS

SECOND SESSION

ON

S. 2666

A BILL ENTITLED THE "GLOBAL ENVIRONMENTAL PROTECTION ACT OF 1988"

SEPTEMBER 14 AND 16, 1988

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THE GLOBAL ENVIRONMENTAL PROTECTION ACT OF 1988

WEDNESDAY, SEPTEMBER 14, 1988

U.S. Senate, Committee on Environment and Public
Works, Subcommittees on Hazardous Wastes and
Toxic Substances, and Environmental Protection,
Washington, DC.

The subcommittees met, pursuant to notice, at 10:00 a.m., in room 406, Dirksen Senate Office Building, Hon. Max Baucus [chairman of the Subcommittee on Hazardous Wastes and Toxic Substances] presiding.

Present: Senators Baucus, Mitchell, Reid, Graham, Stafford, Chafee, Durenberger, and Pressler.

OPENING STATEMENT OF HON. MAX BAUCUS, U.S. SENATOR FROM THE STATE OF MONTANA

Senator Baucus. The hearing will come to order.

I first want to thank all of you for coming today, particularly the witnesses who have expended time and money and—no pun—energy in getting here. I particularly want to thank my distinguished colleague, Senator Stafford, for his very exemplary leadership on this issue. The people of Vermont are very lucky to have someone with the foresight and the solid, good common sense of the senior Senator from Vermont. I particularly want to thank the Senator for his leadership on trying to find solutions to the problems of global warming.

Senator Stafford. Thank you very much. I appreciate that, Mr. Chairman.

Senator Baucus. As we gather here this morning, Mother Nature is changing an area larger than the State of Connecticut. The fires at Yellowstone Park in northwest Montana are the worst on record. Montanans will talk about the fires for generations to come, and about the brave and hardworking men and women who are on the front lines.

This summer's heat and drought, contributing to 68,000 fires already, and burning 4 million acres so far, are but one piece of a complex puzzle in global warming. Today, as on other occasions, this committee has before it a panel of distinguished scientists. It is not often that the scientific community and the political leadership agree. It is not hard to understand why it is not often. Science is the world of absolutes, where facts are tested against other facts. Government is a world of competing interests, where solutions require compromises. In science there is little room for compromise.

Our country has entered a period where both political trends and scientific facts are beginning to converge. Americans are thinking more about the environment. In particular, Americans are becoming more concerned about the greenhouse effect.

The four hottest years of this century occurred in the 1980's. The warming of the earth's atmosphere has been directly linked to the growth in greenhouse gases—the most notable, carbon dioxide. CO_2 concentrations have jumped 25 percent over the past 100 years. In fact, CO_2 concentrations have accelerated at the rate of 4 percent per decade over the past three decades. At present, the burning of fossil fuels emits 5 billion tons of carbon to the atmosphere each year.

In addition, concentrations of methane and CFCs, two other major greenhouse gases, are increasing more rapidly than carbon dioxide. Methane concentrations have risen 30 to 40 percent in the last 35 years, and continue to grow by 1 percent per year. CFC concentrations are growing at the rate of 5 percent per year. Moreover, some trace greenhouse gases absorb infrared radiation up to 10,000 times more efficiently than CO_2, thereby contributing about as much to global warming as does CO_2.

We know that the buildup of carbon dioxide and other greenhouse gases since 1960 may have committed our planet to at least a 4.5 degree Fahrenheit warming. We know that more harmful solar radiation is bombarding us, our oceans and our food chain, as the ozone layer is depleted by chlorofluorocarbons. We know that massive deforestation of our rain forests robs the earth of its natural air purification and cooling system, and we know that record drought in America and devastating floods in Bangladesh—and Hurricane Gilbert—destroy lives and livelihoods. All of these phenomena may be related.

Cynics may charge that legislation and hearings are no more than political posturing around an emotional issue. Let's all be very clear on one point: Combatting the greenhouse effect requires efforts by institutions of government and all Americans, and by governments not only in America but around the world. It will take a careful balancing of competing interests, of competing societies, to reach a solution.

In short, it will take an historic meeting of minds—scientific, political, economic and social—to turn heightened environmental concern into effective global action. Congress has taken the first steps. Legislation before the Energy Committee calls for greater energy efficiency to help combat the greenhouse effect. Senator Stafford and I have introduced legislation calling for direct cuts in the emission of greenhouse gases.

All of us are concerned, and all of us realize that any effort taken by the U.S. must in fact be matched by our global neighbors. A solution lies, I believe, in a combination of several efforts: more efficient use of the energy we consume; development of alternate forms of energy production; tighter controls on greenhouse gases; and a global framework to achieve global results.

There is no time for delay. If current trends continue, by 2030 the Earth will be an average 3 to 9 degrees Fahrenheit warmer than it is today. Even small changes in average global temperature could have a large environmental effect. As we will hear today, we may already be feeling those effects. Scientists warn that major changes in the environment caused by global warming will be irreversible and sudden. It's as if nature tries its best to compensate for civilization, but then suddenly retreats in exasperation.

We do not fully understand the magnitude of these changes, but no doubt the economic, social and political consequences of global climate change will be severe and intractable. Today our witnesses will help us understand the nature of these problems, the ramifications, and also better flesh out some of the solutions.

I would like now to ask Senator Stafford, who is the primary sponsor of the legislation, if you have an opening statement?

OPENING STATEMENT OF HON. ROBERT T. STAFFORD, U.S. SENATOR FROM THE STATE OF VERMONT

Senator **STAFFORD**. I have a brief one, Mr. Chairman. I thank you.

Before the statement, I would like to say to my colleagues on the committee that during the August recess I spent two and a half weeks in China with Senators Leahy and Daschle. My purpose in making the trip was largely to try to understand the environmental problems that are occurring in China as part of the global problems that the whole world faces.

Before the next meeting of this subcommittee on Friday, I hope I will be able to put together a summary of my impressions of that trip and some interesting newspaper stories carried in the China Daily, which is an English language Chinese newspaper, as well as a statement that is being translated from the Chinese, by the counterpart of Lee Thomas, their administrator of what passes for their Environmental Protection Agency, describing his understanding of the problems and some of the things they are trying do to about them in China. They have some problems.

Mr. Chairman, I want to thank you very much for scheduling these hearings on S. 2666, which is sponsored, as you pointed out, by this Senator, you, and Senator Chafee. Although these hearings are on a bill which bears this Senator's name as principal sponsor, I am a realist. There is simply very little to no chance the bill will become law this year. The task of enacting this legislation or something like it will fall on the next chairman and ranking member of the committee in the next Congress, and particularly on the younger members of this committee.

I can say that at every step I have taken along the road towards this bill, and during the years in which I was privileged to serve as the chairman of the committee, the younger members were of great help. Indeed, it is no accident that the second name on this bill is that of the Senator from Montana, Senator Baucus, who is chairing this subcommittee. He insisted upon it as an expression of his personal interest and commitment, and I expect next year his name will probably be the first.

Hopefully, these hearings will lay the groundwork for action in the 101st Congress. Judging by the mail which my office has received, this legislation is getting widespread public support.

Finally, Mr. Chairman, I have to confess to you and to the distinguished scientists who are here, to whom I had hoped to give my full attention, that yesterday the Senator from Vermont developed an extremely painful toothache which seems to be getting my prior attention this morning. In consequence, I am going to have to forego the pleasure of listening to the witnesses, but I assure them I will read their testimony with care. If I leave in a few minutes, it is because I have a date with the dentist.

Senator BAUCUS. Thank you very much, Senator.

We are joined this morning by the very able Senator, and a leader in this effort, from the great State of Maine. Senator Mitchell is cochairing this hearing and chairs the Subcommittee on environmental protection. Senator?

OPENING STATEMENT OF HON. GEORGE J. MITCHELL, U.S. SENATOR FROM THE STATE OF MAINE

Senator MITCHELL. Thank you very much, Mr. Chairman. I join Senator Stafford in commending you for these hearings and for the leadership you have demonstrated in this issue of critical importance, not only to the people of this country but to the people of the world.

1988 has been an historic year for the environment. There were record levels of heat, record high levels of ground-level ozone, record drought, and record levels of forest fires. Are these symptoms of a global system overwhelmed by population and pollution pressure, or are all these events just coincidence? Should we regard them as a warning sign, or should we view them as unrelated events of no common significance. Now, at this very moment, we even have a record-breaking hurricane, although I have not heard anyone yet suggest a relationship between that and the other climate effects which I have just described.

There are no easy or absolute answers to these questions, but we look forward to the testimony of distinguished scientists today and on Friday, who will tell us what they believe will continue to happen if we, the human race, fail to act. Some predict that we will face significant and devastating increases in sea levels; changes in ocean circulation; more hot and heavily polluted summers; shifts in vegetation patterns; more severe tropical weather; and other adverse effects.

In the face of all of this evidence and this compelling testimony, the only prudent course is prevention. We cannot gamble with the future of our planet. We must view these environmental effects as part of a larger system, and we must act now to protect the human environment. Witnesses today and on Friday will give us a better insight into what interrelationships exist between these various events and what steps we can take now to mitigate or to prevent future years from being as historic as 1928 or worse.

Thank you, Mr. Chairman.

Senator BAUCUS. Thank you, Senator.

We are also joined by the Senator from Rhode Island, Senator Chafee. Senator?

OPENING STATEMENT OF HON. JOHN H. CHAFEE, U.S. SENATOR FROM THE STATE OF RHODE ISLAND

Senator CHAFEE. Thank you very much, Mr. Chairman. I look forward to these hearings. They are a follow-on to what we have been doing for a couple of years now, and I just hope that with the added information that has come about, plus the backup testimony of the distinguished group we are having today, that we will propose some legislation to really wrestle with this problem successfully.

Of all the problems facing the world, I think this is the number one problem. We can talk about the possibilities of nuclear war and we can talk about AIDS and all the other horrible things that are affecting us, but this deals with the very globe that we ride on. I think we can learn a lot today, and I hope the accent next year of this committee will be on source reduction.

Continuing with the remarks of Senator Mitchell, we just have to stop doing what we're doing. We have so many warning signs that have frightened the people, but I think they have been good in the long run. I think things like medical waste washing up on beaches just show that we cannot continue doing, as a human race, what we have been doing to the atmosphere, to the oceans, to the air, and to our earth, so today is one more step forward in a long trail, but it is a trail we have to start down immediately.

Thank you, Mr. Chairman, and I want to thank you for holding these hearings.

Senator BAUCUS. Thank you, Senator. Senator Pressler has a statement which we will include in the record at this point.

[Senator Pressler's statement follows:]

OPENING STATEMENT OF HON. LARRY PRESSLER, U.S. SENATOR FROM THE STATE OF SOUTH DAKOTA

Mr. Chairman, I want to thank you for scheduling the two hearings on the greenhouse effect and global warming. The current drought and record heat wave have focused a great deal of attention on global warming and the greenhouse effect. These important issues need to be addressed.

Many reputable scientists and researchers claim that our climate is warming. This summer's heat wave set new records for average high temperatures in much of the Nation. The heat and drought have caused serious problems for farmers, ranchers, and urban areas. Crops have withered throughout the Midwest and in many other crop producing areas throughout the world. Canada, Brazil, Argentina, and parts of the Soviet Union all are experiencing droughts this year.

Ozone levels in urban areas have consistently exceeded attainment levels. This could be an unfortunate preview of future weather patterns. Four of the hottest years on record have occurred in the last decade. Some scientists predict an average temperature increase of between three and eight degrees by the year 2050. The effect of that would be devastating.

Actions must be taken to reduce production of chlorofluorocarbons (CFCs), carbon dioxide and other air pollutants. We should adopt a national goal to reduce carbon dioxide emissions by 20 percent. This can be achieved by developing alternative sources of energy, energy conservation measures and imposing some additional emission controls. Research on global warming and alternative energy should be expanded.

Global warming is a worldwide issue and must be addressed on an international basis. International negotiations to reduce air pollution and to stop deforestation must continue. Deforestation not only plays a significant role in global warming but also contributes to devastating soil erosion.

Mr. Chairman, I look forward to hearing the witnesses' testimony.

Senator **Baucus**. With that, let's begin. Our first panel consists of Dr. F. Sherwood Rowland, Department of Chemistry of the University of California at Irvine; Dr. Carl Wunsch, Department of Earth Atmospheric and Planetary Sciences at MIT, Cambridge; and Dr. Ralph Cicerone at the National Center for Atmospheric Research in Boulder, Colorado. Gentlemen?

Dr. Rowland, why don't you begin.

Mr. **Rowland**. Thank you, Senator.

Senator **Baucus**. And again, thank you for all the time you have devoted to this issue. You have appeared before this committee and other committees many times, and you are one of the leaders in calling attention to the problem. This committee would like to thank you for all your efforts.

STATEMENT OF DR. F. SHERWOOD ROWLAND, DEPARTMENT OF CHEMISTRY, UNIVERSITY OF CALIFORNIA AT IRVINE

Dr. **Rowland**. Thank you for your remarks.

I am going to speak primarily about stratospheric ozone and chlorofluorocarbons, and that is what my testimony is directed toward. In the past 6 months I believe there has been a very sharp change in the view of the scientific community, in the consensus of the scientific community, about what is happening with stratospheric ozone.

I believe there are two components to this change. The first component is, the cause of the Antarctic ozone hole has really been firmly fixed by the expeditions that were sent down there in 1986 and 1987. You now read statements like the following, such as from Physics Today: "The extensive new data leave no doubt that manmade chlorofluorocarbons are primarily responsible for the ozone hole." It is this certainty of opinion that has coalesced in the scientific community, that is one of the factors that changes the view as far as stratospheric ozone is concerned. The chlorofluorocarbons are the primary cause of the loss of ozone over Antarctica.

I think the second aspect which has changed follows the report of the NASA ozone trends panel last March which indicated that there are losses of ozone in the northern hemisphere as well. There are two kinds of measurements, two systems that are working on measuring changes in ozone. One kind is the ground-based system, where you have a number of individual stations, and the other kind is the satellite; the Nimbus-7 satellite carries two instruments that measure ozone.

The best estimates of what is happening globally come from a combination of these two systems. The ground-based stations are of variable quality, some of them excellent, some of them not so good, and the overpasses by the satellite allow you to sort out which stations are doing good work and which ones are not. Then if you concentrate on the good stations and watch over a period of time, you are able to correct for the known degradation of some of the instrumental capabilities of the satellite.

So the combination of the ground-based stations and the satellite give us the best system for measuring total ozone at the present time. We use the ground station to calibrate the satellite, and we use the satellite to make sure the ground stations are doing a good job.

On the other hand, we do know that ozone can be affected not only by man but also by various other things, in particular the solar sunspot cycle. We are at the present on a rising part of the sunspot cycle, and this means that for this natural reason we expect an increase of 1 or 2 percent in total ozone globally over a period of 5 or 6 years, from the sunspot minimum around 1986 to the next maximum in 1991.

The satellite systems have been up only since 1978, not even one solar cycle, so it is very difficult from the satellite measurements alone to sort out what effect might be coming from man and what effect is caused by the variations of the solar cycle. If you look, however, at the Dobson stations, the ground-based measurements, one has records that last for 25 or 30 years, and in one case for 55 years. What one can see here is the change which has occurred over several solar cycles, so that we can eliminate that from the calculation.

If one looks at the Dobson stations in the northern hemisphere, what one finds is that there are 19 stations with good records north of 35 degrees north latitude. Every one of those shows a winter time decrease in ozone, and one can combine these numbers, combine these stations to get band averages. If one looks for, for instance, at the band from 40 to 52 degrees north, which is the northern part of the United States, the loss of ozone, since 1970 is about 3 percent on an annual basis and 4.7 percent in the winter. In the southern part of the United States, the same figures are 1.7 percent on an annual basis and 2.3 percent in the winter.

If I can just point out, too, the NASA Ozone Trends Panel has now put out the chapter summaries, dated August, 1988. This is the most thorough description of what the Ozone Trends Panel did. That is available now, and it has just come out in a published form.

I have two other comments to make. One is that despite the agreement on what is causing ozone depletion, there is not agreement on predictions of the future. The chemistry that is active in the Antarctic is very complicated and very difficult to model mathematically, so that the predictions for the future as far as ozone depletion is concerned are very, very shaky at the present time. I think they will remain shaky for another 10 years, maybe 20 years, so we will have to evaluate ozone loss by measurements in the atmosphere itself.

Finally, I have done some calculations on the concentrations of chlorofluorocarbons in the atmosphere and the effects of the Montreal protocol or of more drastic phaseouts, and I have included those in a graph in my testimony. Effectively, the present concentration of chlorine in the lower atmosphere is 3.6 parts per billion, up from 1.8 parts per billion about 14 years ago and going up at about 1 part per billion per decade. The chlorine concentration would reach 5 parts per billion at the end of the century, and, without any controls, go up to reach 6 at the year 2010 and 7 at the year 2020.

If the Montreal protocol were put in, then the chlorine increase would be about half a part per billion per decade, but it would still be an increase. If a total phaseout of the emissions of chlorofluorocarbons were accomplished within the next decade, then we would go through a maximum concentration around 4.4 parts per billion at about the turn of the century. A total phaseout can limit the further increase to something less than 1 part per billion over what we have now, but it would require a total phaseout.

My final remark is that we need to include carbon tetrachloride in the protocol. This is the most obvious chlorine-containing molecule which is not covered by the Montreal protocol. We can gain even more protection against ozone depletion if we manage to get carbon tetrachloride covered as well as the chlorofluorocarbons.

Senator BAUCUS. Thank you very much, Dr. Rowland.

The next witness is Dr. Wunsch.

STATEMENT OF DR. CARL WUNSCH, CECIL AND IDA GREEN PROFESSOR OF PHYSICAL OCEANOGRAPHY, DEPARTMENT OF EARTH, ATMOSPHERIC, AND PLANETARY SCIENCES, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Mr. WUNSCH. Thank you. I was asked to speak to three items concerning the ocean: what changes in the ocean are observed; the connections these changes, if any exist, might have to the oncoming greenhouse effect; and the potential for changes within the ocean circulation with impact on the atmospheric greenhouse effect. I am in the position, as you will see, of having to be a good deal more tentative than any of us would like, for reasons I will try to explain.

The ocean is changing; there is no doubt about that. As compared to the atmosphere, there are two physical differences that one should be aware of. The ocean is very sluggish. It is a much more dense fluid than air is, and it has a very much larger capacity for storing heat and gases and many other things that exist in both the atmosphere and in the ocean.

In this sense, the ocean remembers the previous states of the atmosphere. It remembers states of the atmosphere for years, decades, even—we believe—centuries, so as we look at the ocean, we are looking into a murky record of where we have been and trying to infer from that where the system as a whole might be going.

Now what do we in fact see? We see a number of different things. We see the greenhouse gases going into the ocean. It is quite clear that the carbon dioxide content of the ocean—you can see the pictures in my written testimony—are increasing. They are increasing with time, and we can track the injection of carbon dioxide into the ocean, and thus the ocean is reflecting the increase in carbon dioxide. We see very clearly, too, the injection of the fluorocarbons, Freons, which do not occur naturally in the ocean. There is no doubt that the ocean is taking up a large fraction of the greenhouse gases.

The ocean is changing in other ways than the carrying of these dyes, if you like, which are injected from the atmosphere. The ocean has clearly warmed in places, at great depth in some cases, warmed in a way that is consistent with the way some people think the greenhouse warming should be taking place: That is to say, one does not necessarily expect the surface ocean to warm first but, as we are seeing, great depth is where the first indications of a greenhouse warming of the ocean can occur. There is also no doubt that sea level is rising. Sea level has been rising for many decades over most, but not all, of the earth.

There is no doubt that these changes are taking place. No one would argument that the increase in the greenhouse gases in the ocean is not a result of what is going on in the atmosphere. Unfortunately, we are not in a position to say definitively that the other physical changes we see—the sea level rise, the warming, the changes in other properties over the ocean—are definitively a result of the greenhouse effect. The problem is, of course, that the ocean is always changing. The ocean has always changed, long before man existed on the Earth, and our difficulty with the great paucity of observations we have is to separate those things which are manmade from those things which the ocean, which couples to the atmosphere in very complicated ways, would be doing all by itself.

And so I cannot tell you definitely that the warming we see at depth is due to the greenhouse effect and that it will therefore necessarily continue. There is nobody who can tell you that. All I can tell you is that we cannot disprove that it is a result of the greenhouse effect. It may indeed be a warning that it is happening; similarly with the sea level rise. So there are changes. There are many others I could list, some of them mentioned in the written testimony.

What are the consequences of this? There is no doubt that there will be a greenhouse warming. It seems to me, not as a meteorologist, but somebody who knows something of the subject, that this is at least as clear as almost anything in meteorology. The probability that the ocean itself is going to remain physically unchanged under the impact of these changes is very small. We expect the ocean to change.

The ocean can change in ways that in fact can make the system very much worse. As I have already said, the ocean is taking up greenhouse gases—carbon dioxide, fluorocarbons, and the others. It is also taking up a substantial amount of heat from the atmosphere. That uptake by the sea of course has the effect of ameliorating the effect on the atmosphere. To the extent that heat and greenhouse gases go into the ocean, they are not resident in the atmosphere, and therefore we see a reduced effect.

But it is possible and, to the extent that we understand the ocean, it is fairly probable, that the ocean will change in ways so that that uptake will slow down, in such a way that less of the greenhouse gases and less of the heat will get pumped into the deep ocean, and remain in the atmosphere. There is no certainty in this. It is possible. Presumably we should assume that in fact this is what is likely to happen, because if we assume that it is not likely to happen and we are wrong, the consequences of the greenhouse effect are going to be even worse.

There are many other things I could say. I will conclude only by saying the following. I was reminded about the super hurricane sitting in the Gulf of Mexico. One of the proposed consequences of an increase in sea surface temperature is the existence of hyperhurricanes: that there would be, should be, many more very intense hurricanes, much more intense than we have ever seen in the past.

Now one hurricane does not make a greenhouse effect, but it is one more indication that perhaps this is what we are beginning to see. It is unprovable in a scientific sense but it may well be the beginnings of a very substantial change in that part of our atmospheric and ocean system.

Finally, I realize that I have been evasive a little bit, in saying I can't prove these things. I am concerned that in 10 years someone else will sit here and be equally evasive, and say, "We don't know." The one final comment I would make is that the scientific understanding of what is going on is clearly rather primitive. The way we are going, the way our Government is facing the problems of doing research on this subject, suggests to me that 10 years from now somebody else will sit right here and be equally evasive, and say, "There are changes. We don't understand them. It may have something to do with this but we're not sure."

Thank you.

Senator BAUCUS. Thank you very, very much, Dr. Wunsch.

Our final witness is Dr. Cicerone. Dr. Cicerone?

STATEMENT OF DR. RALPH J. CICERONE, SENIOR SCIENTIST, ATMOSPHERIC CHEMISTRY DIVISION, NATIONAL CENTER FOR ATMOSPHERIC RESEARCH, BOULDER, CO

Mr. CICERONE. Thank you, Senator Baucus, Senators. I will skip through my prepared testimony so as to condense it, with your permission.

In the time that you have given me, I will try to summarize some scientific data on large-scale atmospheric changes, to outline some connections between pollutant chemicals and their effects and how they may interact and grow larger, and also indicate general support for the goals of this act.

The greenhouse effect is not just a theory. It has been working in nature for most of Earth's history. Without the natural greenhouse gases and clouds, the Earth would be about 40 degrees Fahrenheit colder than it is, and it would be mostly or all frozen over. Our problem now and for the foreseeable future is that we are adding more of these natural gases and others to trap more and more heat in the Earth-atmosphere system, thus adding to the natural greenhouse effect which has been working, and causing a variety of climate changes, not just heating.

A group of scientists critically reviewed available data in 1986, and our results were presented to you in 1987 in a brief report, a copy of which I am holding up, from the National Academy of Sciences/National Research Council. With your permission, I append a copy of that report to my statement.

Senator BAUCUS. Without objection, it is included.[1]

Mr. CICERONE. Thank you. It is entitled, "Current Issues in Atmospheric Change."

The greenhouse gases of concern have continued to increase at about the same rates as are stated on page 4 of that report, and which Senator Baucus summarized earlier. Also, there is more evidence now that the present amounts of these gases are unprecedented. We are definitely pushing the earth into uncharted territory, into a new, higher energy regime whose climate will probably be different from any experienced by humans. And we are no longer free to speculate that maybe past eras did have as much or more greenhouse effect from carbon dioxide and methane and the other gases as where we are headed now.

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[1] The report referred to has been retained in committee files.

As to climate change itself, the list of anticipated climatic effects, which we ranked in order of our confidence that they would occur, has not changed much. Global temperature records and sea level data are being examined now very critically. Recent examinations agree that the world is warming, but the rates of temperature change are somewhat different from scientist to scientist. The amounts of warming are sensitive to how the data are being examined. On the other hand, no magical ideas have materialized to allay our concerns over the coming greenhouse effect. There have been very major changes since this report in scientists' views of stratospheric ozone depletion, as Professor Rowland has just outlined, in those two major ways.

Let me go now to some connections and some potential for surprises. A lot of our scientific research and our national policies on atmospheric and climate change have focused on one question or issue at a time, but there are also interconnections that need to be explored. For example, there are some potential consequences of a climatic warming, in addition to those that Professor Wunsch has just mentioned, that can lead to increased warming or a positive feedback in the system.

For example, with methane it is likely that even more methane will be released to the atmosphere from natural wetland areas and high latitude tundras as temperatures increase, and it is possible that hydrate formations that contain a great deal of methane will break apart as temperature increases. Also, as summer maximum temperatures increase, so will the demands for electricity. Electrical utility networks have to be able to respond to peak power demands. More high temperature extreme events will have to be met.

The highest temperatures that we have experienced to date will be more likely in the future. Thus, there could be more fuel used in producing electricity. With present technology, this will mean more nitrogen oxide and sulfur dioxide gases discharged into the atmosphere. Higher temperatures would also cause more loss of hydrocarbon vapors from many reservoirs.

Then the added nitrogen oxides and hydrocarbons will lead to more ground level ozone pollution, and some of this extra ozone will add to the greenhouse capability of tropospheric ozone. Of course the extra need for electricity will also cause more carbon dioxide to be dumped into the air, and the added SO_2 and nitrogen oxides will also add to our acid deposition. If this kind of scenario runs its course, the climate and environmental changes will be made larger in all of these ways.

We are also concerned about suppressing the normal channel of atmospheric chemistry that consumes methane and carbon monoxide. If this occurs, further methane increases can occur faster than the growing methane sources alone could cause, and this possibility is real even if it is not yet proven.

Feedbacks like these are loaded on top of a disturbed system that is already very difficult to map out and predict. This committee has heard testimony previously on the record of past climate change and how rapidly changes have occurred. Some previous glaciations and weather pattern and ocean current changes have been sudden. Considering our present limited ability for prediction of the effects and their timing on human socioeconomic systems, health and ecology, it is very risky to try to calculate the costs of such poorly defined impacts and then to judge various preventive actions against those estimated costs.

Some strategy, if I may offer some opinions: We are looking at a future where there could be very high costs and serious impacts of climate change, ozone layer depletion, and near surface pollution, in human, economic and environmental terms. I support a multipronged strategy. It seems sensible to do several things.

First, we must intensify scientific research. We have to get started on easier control measures, and we have to identify adaptive practices in the more difficult courses of change and get started on some of them.

You are aware of our limited ability to predict all the environmental consequences of these pollutants and their timing. We must improve, and we can do so with more commitment to basic and applied environmental research. We must map out the behavior of Earth's environmental system and its limits, its resiliency, and its patterns. As examples, I mention at least the need to predict climatic effects on regional scales, not just global ones, and the temporal changes of the next decades to a century. Also, we must learn more about the chemistry of the disturbed atmosphere and of oceanic productivity and circulation. Social science research is sorely needed, also.

There are some control measures we really ought to start on. Some of the easier ones that are identified in S. 2666 are ones on which many people and interests can agree, because there are at least two or more separate reasons for taking several of these actions. Energy conservation is a prime example. We could simultaneously decrease the U.S. trade balance problem, improve our national and industrial efficiency, decrease our strategic dependence on overseas fuels, and decrease our carbon dioxide and methane gas pollution, and lessen our regional air pollution problems. Renewable energy sources are also attractive in more than one respect. Another such example is the further, more stringent control of CFCs, for both important reasons.

But I would like to offer another reason that we should get started on these things, and that is that the United States would be stronger and more respected internationally by reclaiming the high ground, the highest ethical position towards global pollution. As the more difficult control measures are contemplated and the need for adaptive practices becomes apparent, the United States will benefit by having the respect of others.

As several Senators have said this morning, the hot, dry spells of the last two summers have caused all of us to think more about all these effects that we might have to deal with, such as those that other witnesses on the subsequent panels are describing today. But if, for example, our agricultural practices have to change, and if more dependence on nuclear energy is needed due to more energy usage and more population, let's get started now to conceive of safe and productive ways to do these things.

My pitch is that strength and respect will flow to the United States as a protector of the environment, and a substantial market will develop in other countries for agricultural knowledge and the technologies of energy conservation and generation, transportation, chemical production, and other such practices.

Thank you.

Senator BAUCUS. Thank you very much, Dr. Cicerone. Thank you all for your statements. I think it is important to note that there is no disagreement among you, and I take it virtually no disagreement among the scientific community, that the greenhouse effect is occurring; and, second, that the various greenhouse gases—carbon dioxide, methane, and others—are contributing to the greenhouse effect; and, third, that as near as we can tell at this point, the consequences of this phenomenon are deleterious.

There may be disagreement as to the trend, the degree to which this is occurring. There may be lack of sufficient evidence to know, for example, whether the oceans are in fact being warmed up or the ocean level is rising as a direct result of the greenhouse effect, but there certainly is no quarrel that the phenomenon generally is occurring and that the consequences to the world are adverse.

I would like to ask some questions that follow from that a little more directly, to you, Dr. Wunsch. You said that an increase in hurricane intensity is consistent with increases in surface temperature. Is that correct?

Dr. WUNSCH. There have been studies that showed comparatively small increases in sea surface temperatures, from which hurricanes extract their energy—hurricanes are essentially an interaction between the warmth and the energy stored in the ocean's surface and the atmosphere—and there are studies which seem compelling that suggest that comparatively small increases, 1 or 2 Celsius, in the tropical ocean sea surface, can lead to much more intense and much more frequent super hurricanes.

I would emphasize that this is theory, and of course the incidence of a single extremely intense storm does not demonstrate that it is happening, but the theory is actually quite compelling. It suggests that from what we know about hurricanes, that such an effect should occur as soon as there is a measurable rise in the tropical sea surface temperatures.

Senator BAUCUS. You mentioned that the ocean is absorbing greenhouse gases, that the ocean is warming at lower depths, and that the ocean levels are rising.

Dr. WUNSCH. That's correct.

Senator BAUCUS. You also said, though, that you cannot definitively say that this is due to the greenhouse effect. That is, science so far cannot either prove or disprove that phenomenon. Can you tell me, though—I know scientists are loath to do this—but tell me your best guess, what you think, what your gut tells you, and the probability that, based upon your best judgment——

Dr. WUNSCH. What I see is consistent with what you would expect to have happen under the greenhouse effect, and my gut feeling is that we should assume that that is what we are seeing.

We will not be able to prove it or disprove it until it is far too late, if we were wrong in the assumption that this is a purely natural phenomenon. The indicators look like greenhouse indicators. They are not scientifically demonstrable to be greenhouse indicators, but they are not scientifically demonstrable not to be, either.

Purely as an informed citizen, it seems to be that in choosing the course we must take, there is only one choice. If we are wrong and are complacent, we can get ourselves into very serious trouble. If we are wrong, and we assume that these are greenhouse indicators and they are not, it seems to me that all we have done is some of the things that my colleague here suggested we probably ought to do anyway—especially to conserve fossil fuels, with all the other benefits of doing so. It seems to me in any cost-benefit weighing up of the two assumptions there is no contest.

Senator BAUCUS. Well, I guess the second question, you mentioned also that you worry that 10 years from now professionals in your field may be making some of the same statements; that is, the science will not yet be definitively developed so that professionals in your field will be able to state with sufficient certainty that this is all causal.

The question that comes to my mind is the degree to which accelerated efforts and additional resources dedicated to trying to find answers to some of these questions will in fact pay out. That is, there is a certain cost-benefit analysis here that says the more dollars you put in, the more efforts you put in, the more people who spend more time on this, the more likely it is that we are going to find some answers to some of these questions, but obviously there is a point at which we are going to be spending too many dollars, too many resources.

So I would like to ask your best guess, according to your best judgment, as a practical matter, how much more in resources and effort should this country be developing to try to answer some of these questions? Is it 10 percent more, 50 percent more? Would a Manhattan Project type of effort find answers? Would the man on the moon program, that kind of effort, find the answers soon enough? I would just like to know, from your point of view as a professional, what makes sense here.

Dr. WUNSCH. I can give you one specific example, I think, to give you a feeling for the order of magnitude that I am talking about. One of the suggestions that has been made about the oncoming greenhouse effect is that the wind field over the ocean is going to change.

Senator BAUCUS. The what?

Dr. WUNSCH. The wind field over the ocean is meant to change as the atmosphere warms, because it is meant to warm more at higher latitudes than at lower latitudes. The atmosphere interacts with the ocean in large part through the wind field. The scientific community has developed an instrument to be flown on a spacecraft, called NSCAT. I don't need to explain what that is in detail. That instrument is going to disappear for want of $10 million in the budget that was passed in the present session of Congress.

The lack of $10 million has killed this instrument, which would at least permit the scientific community to ask questions like, "What is the wind field over the ocean?"—we don't know what it is today—and "Is it changing over a period of 5 years, 10 years?" To the extent that we can get answers like that, we will be in a position to come back here in 10 years and say, "Yes, we see that the trade winds are weakening," or "the trade winds are strengthening." My fear is that we will come back in 10 years and say, "Well, we still don't know what is going on out over the ocean because you have not given what to us seem like very modest resources compared to the potential financial impacts of this oncoming large-scale experiment we are conducting."

The scientific community has a fairly clear idea of what we need to do over the next decade or so. The amounts of money that are being talked about, in round numbers, are on the order of $25 to $30 million a year. We are not talking Manhattan Project. We are not talking space stations. We are not talking supercolliders. We are talking perhaps a 50 percent or less increase in the kind of effort that we already have, but what we are seeing is in fact a decay in our ability, much less a growth.

Senator BAUCUS. Thank you very much. I have a lot more questions I would like to ask along these lines and others, but my time is up.

Senator Mitchell?

Senator MITCHELL. Thank you very much, Mr. Chairman.

In my opening remarks I identified several climatic events which have occurred this year, and then commented that we are right now experiencing a recordbreaking hurricane, and I wonder if any of you would care to comment as to whether there is any possible relationship between the other changes that have occurred and the hurricane? I know Dr. Wunsch mentioned briefly in his remarks a possible relationship. Why don't I start with Dr. Rowland, and ask the three of you to respond to the question?

Dr. ROWLAND. Well, the scientific work which Dr. Wunsch was referring to was done at the Massachusetts Institute of Technology by Dr. Kerry Emanuel. Essentially what he did was to say that hurricanes rise when the water temperatures in the tropics at certain locations gets above a certain level, above about 80 degrees Fahrenheit.

If you warm the oceans, the fraction of the ocean surface that will be at 80 degrees Fahrenheit will increase, and the fraction that will be at 81 degrees Fahrenheit will increase. That is a very simple, a grossly oversimplified explanation of why one expects to have more hurricanes and more intense hurricanes. That seems very straightforward. One of the reasons it is so compelling is that it seems a very straightforward consequence: If you warm the oceans, then those things which are caused by warmer oceans are going to happen more frequently.

Senator MITCHELL. Dr. Wunsch?

Dr. WUNSCH. That is correct. That is a simplified answer.

Senator MITCHELL. Dr. Cicerone?

Dr. CICERONE. I would add only that this is an example of the type of complexity that we have to get on with understanding, and why it is very difficult for me to listen to someone who says that they can add up all the costs of the impacts that we are going to experience.

Senator MITCHELL. Then from the standpoint of a layman, is it fair to conclude that at least one additional possible effect of global warming will be more and more intense hurricanes, through the sequence of events that you both have described?

Dr. CICERONE. Yes.

Dr. WUNSCH. Yes, that is correct.

Senator MITCHELL. I would like to also ask about the possible adverse effects of changes in ocean circulation. Dr. Wunsch, in your statement you assert that the possibility that ocean circulation itself is going to remain fixed throughout this atmospheric change is extremely small. Are you able to speculate on what effects changes in ocean circulation might have on utilization of ocean resources, such as fishing?

Dr. WUNSCH. That is even more difficult to guess than the climatological changes. The biological community is aware that fish populations do seem to go up and down in response, in part, to physical changes in the ocean—changes in temperature, salt content, and nutrients on which the food chain exists. The presumption is that the changes we now see, which occur all the time, have always occurred, will become greater and even less predictable as the ocean circulation itself changes.

After all, we have spent 100 years roughly studying the biological productivity of the sea, the plankton through the fish, and have a great deal of difficulty in understanding what is going on in a system that has remained largely stable. We are now going to start changing that system, and under some scenarios, if you like, we can make some catastrophic changes in that system.

Senator MITCHELL. Well, it is well known that the richness of the fish harvest in certain areas is at least attributable in part to the current and temperature of the water. The Georges Bank off the coast of New England is one of the richest fishing areas in the world. Is it fair to conclude that at least one possible effect, not yet provable by any means, of this global warming and a rise in temperature, would be a change in both circulation—that is, current—and temperature which could adversely affect this fish resource?

Dr. WUNSCH. Historically, there have been changes in the fisheries resources as water temperatures and currents moved. Some of those changes have lasted decades. Particularly well known are those changes that took place in the northern seas, the most productive, in the change from the Little Ice Age of the 16th and 17th centuries. The fish populations changed their location and population in very drastic ways. That is history; that is known.

Senator MITCHELL. Thank you.

Mr. Chairman, like you I have many questions to ask, but I see my time is up and I will yield to you.

Senator BAUCUS. I thank the Senator.

Senator Chafee?

Senator CHAFEE. Thank you, Mr. Chairman.

I would like to address a couple of questions to Dr. Rowland. Dr. Rowland, we look on you as the expert and the leader in the battle to prevent the destruction of the ozone layer, the release of chlorine, the control of CFCs and now carbon tetrachloride. Could you lead us briefly through the relationship between that effort and the greenhouse effect that results from the destruction of the ozone layer or the release of these chlorine gases?

In other words, you are wearing two hats, it seems to me. You are wearing your ozone battle hat, and now we are on a separate but related subject. Could you tie those in, please?

Dr. ROWLAND. If you want a table of organization, then I think you start with, as your first box, the increasing concentrations of trace gases. Then coming from the trace gases you have one effect which is stratospheric ozone depletion and another which is the greenhouse. The trace gases—carbon dioxide, methane, chlorofluorocarbons—are all increasing in concentration. That is something that is well documented. The increases are relatively easy to measure, and then one asks what are the consequences of having these increases in the trace gases.

Carbon dioxide, methane, and chlorofluorocarbons are complicated molecules relative to nitrogen, oxygen, and argon, the main components of the atmosphere. These complicated molecules serve to intercept infrared radiation, and that is the basis for the greenhouse effect. Any increase in these complicated molecules causes you to worry about the greenhouse effect. You have to go through very detailed calculations, and the most detailed calculations were done by a group of which Ralph Cicerone was a member, which indicate that these trace gases other than carbon dioxide cause about as much trapping of infrared radiation as the CO_2 itself.

Then separate from that you have the question of what happens when these molecules finally do break up. In the case of the CFCs, they break up in the stratosphere and they release chlorine. In the lower part of the atmosphere they are quite inert, and they are absorbing infrared radiation but not decomposing. In the upper stratosphere they are hit by ultraviolet radiation, which is much more energetic, causes the molecules to decompose, and then the decomposition products, the chlorine atoms, proceed to attack stratospheric ozone.

So the relationship is a generic one in the sense that ozone depletion and the greenhouse are both consequences of increases in trace gases. The controls that one may try to put on, for one reason or another, on the sources of these trace gases, will have implications for both of the consequences.

Senator CHAFEE. So therefore, if we can continue the battle to decrease these trace gases, and particularly the chlorine-related ones and the CFCs, we have a double victory.

Dr. ROWLAND. The first move, as far as trying to ameliorate the greenhouse effect, is to get rid of the extraneous gases such as chlorofluorocarbons. That is the first move on the greenhouse agenda. It is also the primary move on stratospheric ozone depletion.

Senator CHAFEE. During testimony in past hearings, we have heard about "good" CFCs and "bad" CFCs, and trying to get substitutes for automobile air conditioners and so forth. Do those CFCs that we think we can use to do the cooling have the same effect as far as the greenhouse effect goes?

Dr. ROWLAND. In each case you have to do an individual study to see where that particular molecule absorbs infrared radiation. If you are outside the atmosphere looking in with a satellite, you will see there are regions in the infrared that seem to be transparent. There are other regions which seem to be blocked out, for instance by carbon dioxide. If your molecule happens to absorb in the transparent region, then it is very effective. If it happens to be overlapped with carbon dioxide, then it is not an important greenhouse gas, and that is a question for individual study of the individual molecules.

Incidentally, I should say that there has been an evolution this year. Now the term "CFC" has evolved into CFCs, meaning chlorofluorocarbons, and HCFCs, meaning hydrochlorofluorocarbons. In your description the CFCs are ones that do not contain hydrogen and therefore react only in the stratosphere. Industry is now identifying those substitute molecules as HCFCs to indicate they have hydrogen in them. They can be attacked in the lower atmosphere. If they are attacked in the lower atmosphere, then they are less greenhouse problem; they are also less stratospheric ozone problem.

Senator CHAFEE. So that's a new term we add to our lexicon.

Dr. ROWLAND. And they are adding also HFC, which leaves out the C, which means there is no chlorine, and if there is no chlorine——

Senator CHAFEE. Please, only one lesson at a time, doctor.

I see my time is up. Thank you very much.

Senator BAUCUS. Senator Reid?

Senator REID. Thank you, Mr. Chairman.

They say ignorance is bliss, and I think most of us wish we hadn't come to this hearing this morning because we learn a lot of things that really we wish weren't so. I am particularly struck by the statement on page 5 of Dr. Wunsch's statement. He talks about where we will be 10 years from now, and also Dr. Cicerone, on page 6 of your statement, you also put as your number one strategy to attack the situation that we need to intensify our scientific research.

It is clear from each of you—even though I didn't specifically mention Dr. Rowland—it is clear from each of you that we are greatly lacking in research scientists, research projects, research generally in this field. Is that true? Would you all three agree to that, or do we have enough research going on?

Dr. WUNSCH. Certainly research scientists have made plans to try to do something about this situation. As I said, perhaps a little strongly there, my feeling is that the U.S. scientific community has been reduced to beseeching the Government to let us get on with it. We pretty much know what we need to be doing over the next decade.

Senator REID. But you don't have the resources to do it.

Dr. WUNSCH. We do not have the resources.

Senator REID. Now do you other two gentlemen agree to that statement?

Dr. ROWLAND. I think from the standpoint of atmospheric chemistry, it is a relatively new field in the sense that it may be 10 or 15 years old in its present embodiment. It is developing rapidly, and one has a question as to how much money can be satisfactorily used. I think if one threw 10 times as much money at atmospheric chemistry, that it would be very difficult to spend it.

Senator **Reid**. Do you agree, Dr. Wunsch?

Dr. **Wunsch**. I agree. As I have mentioned, we are talking comparatively small sums of money, even compared to what we already spend.

Senator **Reid**. Okay, but you have indicated, for example, the instrument to test the winds on the oceans, that is a $10 million item. But still in response to my question, for example, Dr. Wunsch, is there enough research being done now on the oceans? Are there enough resources?

Dr. **Wunsch**. No, there is clearly not. There clearly is not, compared to what we can tell you should be done.

Senator **Reid**. That is not a close call, is it? I mean, there is clearly not enough work being done to study our oceans. Is that a fair statement?

Dr. **Wunsch**. That's correct.

Senator **Reid**. Dr. Cicerone, would you agree to that?

Dr. **Cicerone**. Yes, Senator Reid. I recall being here in December, I think, of 1985, and I was asked a question that made me very uncomfortable because we had asserted or I had asserted that within the next couple of years I thought we would know enough about the Antarctic ozone hole to be able to say whether it was caused by human activities or not, and I was sticking my neck out. So someone here picked up on that and said, "Well, do the agencies such as NASA have enough funds to do the work?" I swallowed hard and said yes. If you were to ask me the same question today, I would say no. I see strains that have developed in—

Senator **Reid**. Doctor, if I could interrupt, that is the lead-in to my point. Picking up on something that two of you also said, that we have to go on the assumption that what we know now dictates that we must do something, if we are wrong, we have lost nothing, but if we don't do something based on the information we now have, by the time we learn that disaster has struck, it's too late. Is that a fair statement?

Dr. **Cicerone**. I think it's fair, but I think there is a more positive light that we really should try to put on this, and not all of us have been very good at this. That is, there are gains to be made here. This is the real world we are dealing with.

Senator **Reid**. Okay, but I have a point I want to make.

Dr. Wunsch, would you agree with the statement that I just made?

Dr. **Wunsch**. Yes, I agree. I think it is reflected in my own testimony.

Senator **Reid**. We hear all the time from the administration that we need more research on acid rain; we don't have enough facts now. I think with the facts that we have, for example, on acid rain, we should have done something 20 years ago, 10 years ago, 5 years ago, certainly now.

We hear a lot about new compounds. There are 5,000 or 6,000 new chemicals that we use every year in this country. EPA has no cross-referencing. What about the thousands of new ones that come aboard every year?

I think that we have to recognize—and certainly I know that this committee does, and I congratulate Chairmen Baucus and Mitchell for holding these hearings—we have to start learning some things we would rather not know about. It staggers the imagination to think that, very likely, we are going to have more hurricanes and they are going to be more intense than they were. I would rather not know that, but I think we have an obligation to not only this Congress but this Nation to start bringing out some of these facts.

We have a trillion dollar budget, a trillion dollar budget. It seems to me that we could, for items of construction rather than destruction, we could spend a few million dollars and give you gentlemen and others in the scientific community more tools to work with.

Senator BAUCUS. Thank you very much, Senator.

Senator Durenberger?

Senator DURENBERGER. Thank you, Mr. Chairman.

Dr. Cicerone, thank you for reminding us all of December of 1985. I think we were all here then, and we are all here now, and our views continue to change. I think our commitment is about the same, and in the interim we have made some progress. Some of the people on this committee, my colleague from Rhode Island I know especially has, and perhaps it was in part as a result of those hearings we had here, made some very remarkable—measured in our capabilities around here—progress on certain fronts.

But you were about to say something in response to Senator Reid's question about there are some gains to be made from this situation. Would you elaborate on that a little bit?

Dr. CICERONE. Thank you. Well, simple gains in terms of efficiencies are very obvious, and the ones that we mentioned earlier, the multiple gains that can be had by some of the more sensible actions, but I honestly see some gains to the United States by once again being the world leader in terms of taking the highest ethical positions towards protecting the global environment. I just see respect accruing to the United States, respect that can be added to and substituted for some of our military strength. There are also economic gains, if we can take the lead in the technologies that are needed to do things efficiently and productively. That is the kind of positive situation I was looking at. It's the same old story. There is a lot of faith that we can put into scientific investment, and I see it here, also.

Senator DURENBERGER. Let me go from there, then, to ask all three of you what the feeling is of the scientific community in other nations, in the Orient, in Europe—both western Europe and the East Bloc—on the global warming question. Is there a similar concern for climate changes in other elements of the international scientific community, and what does that mean to the United States and the role that the United States should be playing?

Dr. CICERONE. May I just say something quickly? I know of the new effort that started in West Germany, that may be embracing all the political parties, to prepare position papers that they may all share in their coming elections toward the global greenhouse effect. They are concentrating on energy efficiency and any other measures at hand, looking at all of these chemically perturbing things.

Dr. ROWLAND. I testified to the German Parliament in March, where they had a commission of 11 Members of Parliament and 10 scientists that were holding meetings, really it sounded as though every week. This commission is now preparing these policy papers. I was testifying about the controls on chlorofluorocarbons, but they have gone much beyond that obvious step, to talking about how they could cut down on carbon dioxide emissions. They have been talking about policies which would reduce carbon dioxide emissions in western Europe and particularly in West Germany, and they are already about twice as efficient in their energy use as the United States is.

I think in terms of the awareness of trace gases in one form or another, I have been made quite aware of activities in Europe. There was a demonstration; 5,000 people marched in the center of Rome in May to save the ozone layer. And there are posters all over West Germany. I just returned from a trip to West Germany and Austria and France, and in West Germany there are posters all over saying, "Do not use chlorofluorocarbons," or blaming the West German manufacturer Hoechst for destroying the ozone layer. I saw it in Germany, I saw it in Austria. I must say I didn't see any evidence in France that there was any awareness.

Senator DURENBERGER. Dr. Wunsch?

Dr. WUNSCH. I would only add that of course the world scientific community has been struggling to put in place scientific programs in order to try to come to grips with what is happening. There is a program called the World Climate Program, with a World Climate Research Program.

You know as well as I do that Third World countries of course are extremely ambivalent about such alarms. They have more pressing problems, in their views. The Soviet Bloc or the Eastern Bloc of course seems to be just beginning to recognize the seriousness of some of its own environmental problems. Some of it has been in the newspapers recently, a public recognition that they have done things to their environment that are potentially catastrophic.

And so there is this movement, I think all over the world, in which governments are beginning to listen to scientists who have been in some cases warning for years that things are being done to the environment that have consequences not tomorrow or next year but a decade down the road. Well, eventually the decade gets here, and I think the Aral Sea is the one that has been in the newspapers lately, a catastrophic change in that part of the Soviet Union which was pointed out by Soviet scientists many years ago as possible change. I don't think they quite understood how bad it was going to be, even the scientists.

Senator DURENBERGER. Thank you.

Senator BAUCUS. Thank you, Senator.

Senator Graham?

OPENING STATEMENT OF HON. BOB GRAHAM, U.S. SENATOR FROM THE STATE OF FLORIDA

Senator GRAHAM. Thank you, Mr. Chairman. Mr. Chairman, I would like to ask unanimous consent to enter an opening statement in the record?

Senator BAUCUS. Without objection.

Senator **Graham**. And I wish to commend you and Senator Mitchell and the others who have called this very timely hearing.

[Senator Graham's statement follows:]

Opening Statement of Hon. Bob Graham, U.S. Senator From the State of Florida

Mr. Chairman, your hearing on global climate change is timely. We were warned years ago that we could experience a greenhouse effect if we continued to emit carbon dioxide and pollutants at constant or increased levels. Then, many wrote this warning off as alarmist.

This summer brought people around to re-thinking the possibility of such a phenomenon. Much of the country experienced record high temperatures. Here in Washington, we felt the heat, coupled with lenghty periods of heavy ozone. A pollutant in the lower atmosphere.

Higher in the stratosphere, we are hearing of increasing evidence that the ozone we need to protect us from ultraviolet rays is disappearing at certain times of the year.

The combination of our continued emissions and production of ozone-destroying chemicals could serve to exacerbate the problem. With higher temperatures come higher waters as the polar ice caps melt. Florida is particularly vulnerable as a State surrounded by water on three sides.

The Everglades is a fragile system dependent on a delicate balance of fresh water and sea water. A rise in ocean levels will substantially change this ecosystem. Erosion of our coastline is a problem we continually face in Florida. Much of the area we are trying to renourish would be underwater with a rise in sea level.

Major cities on the coast would lose beach-front areas. The Keys could be covered by water.

It is time we face our responsibility in preventing a full-fledged global warming. Senators Stafford and Wirth are to be commended for their legislation to address the problem. I look forward today to hearing from witnesses on Senator Stafford's legislation.

Senator **Graham**. I have this morning attended a breakfast sponsored by the Congressional Research Service on this same subject, and one of the concerns that was expressed there was the need to have an activist research program in order to enhance our knowledge as a predicate and a complement to specific actions. What is your sense of the current state of a coherent research effort in this area, and if you were a member of this committee, what would be your course of action to develop such a plan which we could then support?

Dr. **Rowland**. The atmospheric chemistry community as a group made such plans several years ago. It involved basically over a 5-year period approximately doubling the amount of support. That information can be made available. I think Dr. Cicerone may even have it with him.

Senator **Graham**. And what was the disposition of that 5-year research plan?

Dr. **Rowland**. Well, this was passed on to the political side for hopeful action, and certain aspects of it were included, I think, in the budgets for NASA and NSF, and so on. But it gets very dissipated by the time the money actually comes around. The National Science Foundation budget for atmospheric chemistry was actually cut a little bit this year. They were talking about the expected increase, but the amount actually came down a little bit because it got caught in the same zero budget game with the space station. When the space station got more money, the National Science Foundation got less, and atmospheric chemistry in NSF got less.

Over a period of time the amount of funding has been going up, but it does so in an irregular way.

Dr. **Cicerone**. Senator Graham, there are also plans toward a Global Change Research Program involving many nations. I am sure you have heard about it. I think one of the pressing needs there is for the U.S. Government to decide how to coordinate. You emphasized the word "coherent," how to make a coherent attack, and I think one of the missing pieces now is how the global change research sponsored by the United States can be organized at a high level. There have been proposals that OSTP Committee on Earth Sciences be strengthened and things like this, so these are steps that can be taken to use the money efficiently and coherently, I think, but I don't think the problems are solved in terms of organization.

Senator **Graham**. What recommendation would you have to this committee if our goal was to secure a coherent, multiyear research scheme which would provide us with the increments of information which the scientific community felt was most necessary in order to take informed public policy action?

Dr. **Rowland**. I would certainly go to that program as outlined by the atmospheric chemistry community a couple of years ago, and we can provide that for you if you would like to have it.

Dr. **Wunsch**. If I could interject, the oceanographic community is about to go to a major international conference in Paris in November with a complete U.S. national and an international plan for tackling precisely these questions: What is going on, and what are the consequences likely to be? From a purely U.S. perspective, we are going to that conference in a very uncomfortable position of having to say we do not know whether the United States Government, which ought to be the largest player by all rights, has been able to make up its mind whether it wants to do this or the extent to which it can make commitments to carry this forward.

It comes down to such mundane and specific things as the wind measurement that I mentioned, which too got caught up in the space station increase in the last minute, and so you find that a decade of planning that has gone into this is suddenly placed in jeopardy by events which are out of the control of the scientific community and in which we seem to have very little voice. It is the issue of sustaining decadal science—this is decadal science—in an atmosphere in which all budgets and all plans are in jeopardy on a year-by-year and sometimes it seems like a week-to-week and day-by-day process.

That is the very uncomfortable position the scientific community is in. We are looking at 10- to 20-year problems, and yet we do not know today what kind of resources we will have, what commitments will this Government make to do things for next year. We need some stability and some long-term understanding that our problems are not solved by one-time authorizations to do things. This is simply incompatible with the kind of scientific problem that we are dealing with. The greenhouse and other climate changes are not going to be resolved on a 1-year budget cycle.

Senator **Graham**. Thank you.

Senator **Baucus**. Thank you, Senator.

I wonder, though, if you could tell us, are American efforts compared with other countries—Germany or any other country that you might think of—are they comparable with those countries? Are they slacking off? Are they accelerating beyond those other countries' efforts? I would just like some very rough sense of how American efforts compare with some other countries, in trying to answer some of these questions.

Senator CHAFEE. Mr. Chairman, when you say "efforts," do you mean Government or total efforts, including the private sector?

Senator BAUCUS. I mean total. I mean total, private and Government combined.

Dr. WUNSCH. In my field, which is a special one, the U.S. is the dominant player, has been, has had international leadership in this field since the end of the Second World War. On this decadal time scale I am talking about, it is quite clear that our leadership is declining. There are examples of instances in which we as American scientists have been forced to go begging to our colleagues, for example in Europe, for facilities that we simply cannot get in this country any more. Any American oceanographer who would seriously like to work in the circumpolar regions around Antarctica must today go to either his German or his Soviet colleagues for adequate ships in order to get down there to do anything of any use. That is a big change from 10 years ago.

Senator BAUCUS. Now is American leadership declining because we are spending less effort, or is it declining on a relative basis because other countries are accelerating their efforts?

Dr. WUNSCH. It's a bit of both. I would not paint the U.S. as backward compared to the other countries. All countries are having budget troubles. All countries have difficulties in making decadal plans, but over the last 10 years we have lost our edge. We have lost a lot of our capability. We are now driven to do things with countries abroad that have acquired leadership in many of the most important things we do.

Another example is the studies of ice cores, which have proved very important in the study of past climates. The U.S. is hardly a factor in this at all. It is the Swiss, the French, and the Soviet Union. The U.S. provides some logistic assistance. We are no longer the scientific leaders in this kind of work.

Dr. CICERONE. I think in the study of stratospheric ozone change, though, the U.S. has been so strongly in the lead that many of my colleagues from other countries wish that they could get involved in our effort, but I would agree with everything that my colleague just said.

Senator BAUCUS. Yes, that concurs with my impression, too, that in atmospheric ozone we are really in the lead but in other areas we have a problem.

Dr. CICERONE. Maybe we were causing those problems, but we also were at the lead of cleaning them up.

Senator BAUCUS. I think that's right.

Dr. ROWLAND. In global effects of trace gases, the U.S. has been the leader, and there has been substantial contribution from West Germany. As I look at the West Germans, a few of the people there, the German Max Planck Institutes seem to have much more stable funding. They can make longer term plans in a way that is more difficult in the United States, but they don't have—I don't think the total German funding is anywhere up to ours. Probably on a per capita basis it's close to ours, but they have strong programs, and the rest of western Europe much less strong than the U.S. and Germany.

Senator BAUCUS. Senator Mitchell made a very interesting point with you, Dr. Wunsch, essentially that ocean current changes may be caused by greenhouse gas emissions, the greenhouse effect, and I am wondering whether you can also comment on whether the greenhouse phenomenon may have an effect on, or even probably, is it a directly a cause of say the dry conditions, the drought conditions in the country and the world, maybe as remotely as the increase in forest fires, smog levels, other phenomena? Very, very briefly, I wondered if there is any potential causal connection there, in your judgment?

Dr. WUNSCH. I'm afraid the answer is a definite maybe. The main example we can point at is the El Nino effect which has had a lot of publicity the last few years, in which it has been shown that changes in conditions in the tropical Pacific Ocean seem directly connected to droughts in Africa, changes in the monsoon circulations, and torrential rains on the coast of California, and so there are clear examples of connections between changes in the ocean and changes in our weather and climate. We simply don't know enough about how the ocean changes on a more global scale from month to month and year to year, to have any kind of connecting links. So it is quite possible that it is true, but there is no definite evidence one way or the other.

The point I would make is that the El Nino phenomenon, which is a massive and obvious phenomenon, was known to the first Spanish explorers who came to the coast of Ecuador and Peru in the early 1500's. It is only within the last few decades that there has been recognition that this ocean phenomenon in fact is connected to the weather over the United States and all over the globe.

We suspect there are many other much more subtle phenomena going on in the ocean that are connected to our weather, that we may have known about for 300 years—that is not very likely, but possible—but nobody has actually been able to understand or demonstrate the connection. It is simply a reflection of how little we know about how the ocean changes and how it connects to the atmosphere.

Senator BAUCUS. Is it the judgment of the scientific community that the consequences and the effects of the greenhouse phenomena are gradual and linear, or is it the judgment that it is sort of level and then all of a sudden there is an explosion, a jump, a break, a bubble?

Dr. WUNSCH. We of course tend to be cautious people. We don't like to paint scary scenarios. We don't like to hear bad news either. I would say that most people's judgment is that it is likely to be gradual and slow.

On the other hand, we are fully aware in science of systems that do change abruptly and unpredictably. Many of my colleagues will tell you that they suspect that we may be dealing with a system capable of very rapid and unpredictable shifts. "Rapid and unpredictable" in this context would be tens of years, not something today or tomorrow but tens of years.

We can neither prove nor disprove the possibility that, for example, the ocean will entirely switch states. There are theories that say the ocean circulation could be entirely different, and we could push it into such an entirely different state by some inadvertent change.

I don't think that view is shared by anything like a majority of scientists, but of course science is not done by majority vote. We can neither prove it nor disprove it. It remains a possibility that we would be faced with a catastrophic shift. My personal view is that's unlikely, but I would not want to go on record as saying that it's impossible.

Senator **Baucus**. Thank you.

Senator Chafee, any more questions?

Senator **Chafee**. Just a couple.

First I would say I share your admiration for what the Europeans are doing, but I also would point out that the West Germans, as of the last information I have, haven't even banned CFCs in aerosol, which is about the easiest step anybody can take. I don't want to indulge in a flag-waving exercise here, but the U.S. hasn't done too badly.

In connection with what Dr. Cicerone is saying about the U.S. taking the high ground for moral reasons in all these environmental efforts, we want to do that and this committee will certainly push in that direction, but we are in the problem of should we go it alone, at our own pace, which would be faster and will cover maybe 33 or 40 percent of the problem, or should we move as a leader of the other nations, trying to drag them along with us, so we move in concert and thus maybe cover 80 or 90 percent of the problem?

That is what we went through at the Montreal and prior meetings. It's a tough call, but my own judgment has been, and I think most of you probably share it, is that it's better to move along with the other nations, leading them, because they will say, "Well, if the U.S. is going ahead, we don't need to go ahead." You know, that's their answer.

Let me ask you a question. I will ask each of you. If we warm up the globe through the massive increased population we have now, burning more fossil fuel, creating more carbon dioxide, the release of these trace gases that has never been seen before on this scale, thus the globe gets warmer and the greenhouse effect is there, doesn't it logically follow that the ice is going to melt, that there are going to be higher sea levels and all of the catastrophic effects that we hear about with the greenhouse? What is going to change it? Why all the doubt? What is going to reverse that? What happens that we are missing here, if that scenario I have portrayed—not I, many others have portrayed—isn't going to take place?

Dr. **Wunsch**. Could I respond to that? I think the first answer is, there is not much doubt. Where the argument lies is how fast it is going to happen to us. If these catastrophic effects occur over the next 20 to 30 years, we have a very, very serious set of immediate problems on our hands. If we could be confident that we have 300 years to make an adjustment to these things, then I think there is a different strategy, both for the Government and for the population as a whole. So I don't think we are really arguing about whether or not it is going to happen. I think all we are doing is voicing some concern that we don't know precisely how it is manifesting itself today.

Senator **Chafee**. But if we don't know, and the only question is when, hadn't we better start immediately on that path?

Dr. **Rowland**. Yes.

Dr. **Cicerone**. Yes.

Dr. **Wunsch**. I think we agree, yes.

Senator **Chafee**. I know scientists like to be cautious, but shouldn't we all realize the consequences if we don't do something?

Dr. **Wunsch**. I think you are hearing unanimous agreement that it is a likely happening, that it will happen, and that we should start right now under the assumption that it is here.

Senator **Chafee**. The changes that man hath wrought on this globe are totally unlike any situation that existed with the Little Ice Age of the 1500's and early 1600's. The globe gets warmer, so we run more air conditioners, so we generate more electricity, so we release more carbon dioxide, so we heat up the globe more, and last summer was a perfect case in point, where I saw we had the highest usage of electricity in the history of the country.

Senator **Baucus**. Thank you. Well said.

Senator Reid, any questions?

Senator **Reid**. No questions.

Senator **Baucus**. Senator Graham, further questions?

Senator **Graham**. Yes. I would like to ask some questions on the international dimension of research.

What is the status of collaboration at a formal level internationally?

Dr. **Rowland**. At a formal level? I think most of the research is done on a national basis with very strong informal arrangements, rather than with formal government-to-government collaborations. My own research group I think has participated in only one effort that involved an international effort in that sense. We had some people on board a French airplane when it was flying, but most of our work is done on a national basis. On the other hand, we see the people that are doing the same kind of work internationally every 3 months, so there is a lot of interchange of information, but generally they are still national programs.

Dr. **Wunsch**. Oceanography is perhaps a little different. It is and always has been an extremely international subject, for fairly obvious reasons. There is a formal organization that falls under the World Meteorological Organization, the International Council of Scientific Unions, and various intergovernmental bodies, for the purpose of studying climate change, and there are remarkably complex international agreements with these organizations and countries, and between countries themselves.

The arrangements do range from very formal U.N.-connected programs right down to the extremely informal kind of bilateral thing—one scientist in one country going to sea with a scientist from another country on a third country's ship, in some cases. It is a very complex web that at one level is extremely formal—perhaps not the most useful part of the organization, but it exists.

Dr. ROWLAND. That formal level exists for us. I just tended to leave it out because I didn't see much coming out of it.

Senator GRAHAM. It has been suggested that in addition to the research at a scientific level, that there also is an important role for research at a legal or political level, identifying what are the areas of greatest urgency and where there is likely to be the most international consensus for moving forward on these issues. What is your sense of the state of international recognition of the priority for international treaties and agreements, building off the agreement which has recently been reached in Montreal on CFCs?

Dr. CICERONE. Well, right now there is a lot of, I would say, naive hope that the same kind of international machinery can be brought to bear on the greenhouse effect. The reason I think it is naive is that a great deal of effort and infrastructure went into the ozone agreement over the years. There was a very active community of researchers. There were people going to meetings together and arguing for a period of years, and that hasn't happened yet on the greenhouse effect, as far as I am aware.

On the social science side or the economic assessment side, I think the situation is worse. I think that we get caught up in very simplistic arguments over, "Why spend the money today when the discounted dollar is going to be worth so much less so many years from now?" These start from assumptions that we can cost out the impacts now, which I think are very poorly based.

How many times this past summer did you gentlemen hear a new news story about the effects of the drought that tweaked your imagination, something you hadn't thought of before? I'm afraid that is the stage where we are, just beginning to appreciate those connections, things that we have been taking for granted, costs that we thought we had paid once and won't have to pay again. I think some serious experts and some good common sense have to be used to think through the system that we are playing with, and what are the things that are going to be changing and cost money to do right and to be productive, so I think a lot of social science and political science and economic analysis has to be done, and that the present methods are probably flawed and not up to the task.

Senator BAUCUS. Thank you all very much. You have been very patient and very helpful. Thank you for your attendance this morning.

Our next panel consists of Mr. James Overbay, with the Forest Service at the USDA; Dr. John Schnittker, Schnittker Associates in Washington, D.C.; Dr. Robert Bruck, Department of Plant Pathology at North Carolina State University at Raleigh, North Carolina; Dr. Dewey McLean, Department of Geological Sciences, Virginia Polytechnic Institute in Virginia; and Dr. Timothy Weiskel of Harvard University in Cambridge.

Thank you very much, gentlemen. I am going to more assiduously observe the red light, because we have a little less time remaining and a bigger panel. Therefore, I would like you to summarize your statements in 5 minutes—that's what time the red light goes on—and I will encourage members of the subcommittee to observe the time limit as well.

Mr. Overbay, why don't you begin?

STATEMENT OF JAMES C. OVERBAY, DEPUTY CHIEF, U.S. FOREST SERVICE

Mr. OVERBAY. Thank you, Mr. Chairman and members of the committee. I appreciate the opportunity to participate today in this hearing on the effects of global warming. I will summarize my statement.

I would like to address today four main areas: the present drought and how it affects fire danger in our national forests; a summary of the last two fire seasons; the effects of the drought and related fires on other national forest system programs; and last just touch on Forest Service Research on fire and atmospheric effects. I also have available for the committee copies of a summary of today's fire situation that was compiled this morning from our fire center in Boise, if you would like those statistics.

The prolonged hot, dry weather conditions have resulted in critically dry fuels, including dying and dead standing trees and an accumulation of dry woody slash on the forest floor. While forested lands throughout the United States are affected, conditions are most critical in the West. This is the fourth consecutive year of drought in several parts of the country. However, the drought is more widespread and severe this year than in previous years. Almost every one of our 156 national forests is experiencing some type of problem related to the drought conditions.

The Forest Service uses several indices of long-term drought to help us estimate conditions. One of those indices, the Palmer Index, shows some form of drought affecting 80 percent of the climatic divisions within the United States, and 36 percent of the country falls within the severe to extreme range. Maps showing predicted fire potential based on this index are available, and I would like to just give you a real quick look at those.

This first map shows our predicted fire potential that was made August 5th through September 9th. The red areas show the extreme; high is yellow; medium, blue; and low is in green. As you can see, the areas particularly around Yellowstone and in Idaho and California were predicted to have extreme fire potential back in August.

The very latest summary just prepared, which predicts into October, shows some shift, but again there are extreme conditions predicted generally throughout the West, particularly in the northern tier of States and in California. That is where we are experiencing our most severe fires right now.

Because of this drought, the moisture content of the live trees is at dangerously low levels. We have found that the moisture content of large dead trees in some areas is lower than that normally found in commercially kiln-dried lumber. Of course, when we get these kinds of conditions and we get fire starts, we find that the fires become very large very quickly and are very difficult to suppress.

Although this drought period we have been experiencing during the past few years is severe, it is not without precedent. There have been a number of severe drought periods recorded in the 1800's and the early part of this century. Most of these droughts have been associated with catastrophic wildfire events.

Just a quick summary of what has happened in the last four fire seasons: The average number of national forest acres that burned from the period 1978 through 1984 was 130,000. In 1985 over 560,000 acres burned, and in 1986 353,000 acres burned. Last year, over 63,000 fires burned a total of 4.4 million acres, and of that, 1.2 million acres was on the national forest system. The greatest impact was in northern California and in southern Oregon.

The 1987 season was considered the most damaging to national forest system lands since 1919. However, this year the present activity is greater than it was at this time last year. So far in 1988, nearly 69,000 fires have burned a total of over 4 million acres in the United States, including 2 million acres in Alaska. Just today we have 23 major fires burning on approximately 1.9 million acres which continue out of control.

Over 1.4 million acres have burned in the greater Yellowstone area, which includes both the national park and the surrounding national forests. I will show you real quickly what those fires look like in Yellowstone. The yellow portion of this map is Yellowstone Park, and of course Grand Teton Park is to the south. The green portion is the surrounding seven national forests. The areas shaded in red are where fires have burned in the Yellowstone area, affecting principally the national park but also the surrounding national forests.

Also, to give the committee just a rough idea, this is where the major fires are currently out of control in the West. You can see they are concentrated in northwest Wyoming and in northern Idaho, but we are also getting some significant fires out on the West Coast in the States of Oregon, Washington, and California. This pattern of fire follows very closely that predicted fire behavior from the drought index.

Have I run out of time?

Senator BAUCUS. Can you summarize in about 1 minute?

Mr. OVERBAY. Okay. Well, there are a number of other environmental effects, of course, that result from these fires. Some concerns that we particularly have are what is going to happen with runoff that we get this winter and this spring. There is a lot of risk of soil erosion. There is going to be displaced wildlife. There have been effects, of course, on forage production. There has also been some considerable impact in loss to property and life. Just this last 2 days a severe fire in California burned 93 homes.

The drought is also taking its toll on a number of other activities, such as reforestation of trees and grasses that have been planted. We are suffering losses as high as 30 percent in some parts of the country. The drought is also making trees more susceptible to attack by insects, and we are seeing this activity increase.

We expect stream flows to diminish. This is going to have impacts on recreation, fisheries, and wildlife, and watershed resources. Some communities aren't going to have water supplies. There are a number of continuing effects that occur from this.

We have stepped up our research efforts. We have developed a proposal that we have already implemented. We intend to intensify our research efforts in the 1990's to look at all of the relationships of this continued drought. We will study the effects that the changes in the atmosphere are having on the forest resources, and also what effect the changes in the forest resources might be having on the atmosphere.

Senator BAUCUS. Thank you very much. We will have some questions when we get to that portion.

Dr. Schnittker?

STATEMENT OF DR. JOHN A. SCHNITTKER, PRESIDENT, SCHNITTKER ASSOCIATES, WASHINGTON, DC

Dr. SCHNITTKER. Thank you, Mr. Chairman. I have a statement I would like to have in the record, and I will summarize it.

Senator BAUCUS. Your statement and all others will be included.

Dr. SCHNITTKER. On the question of global climate change and world food supplies, like almost everything else, we need to know more, as panel one said, but we also need to act on what we know and sometimes to take risks by acting on what we are not quite sure that we know. So on the question of food supplies, since they are so critical to human life, we need to err on the side of plenty, if we err at all through Government planning.

Following up on that point, Congress and the new administration will need to take bold steps early in 1989 to be sure that the potential production of grains and other products in the United States is being used actively and aggressively in the immediate years ahead to replace the reserves that we will have used up because of the drought which is just now ending. The stability that we enjoy in grain and food prices and supplies now and for the next 8 or 10 months is based upon the fact that we literally had unmanageable surpluses, not simply reserves, and it's a good thing we did. All of our old concepts on grain reserves, the size they need to be, and the way they are handled in the United States, need to be reviewed and revised on an urgent timetable in 1989.

Thirdly, food, like climate, is international. The U.S. should take the lead now in placing not only global climatic change but its impact on world food supplies and the relationship to world food reserves on the international agenda, formally and informally. The last time this was done, some 12 or 14 years ago in the FAO, discussions of a world grain reserve were actually inhibited by U.S. negotiators rather than led by them. This ought to be reversed. We ought to be taking the initiative in the same way that Dr. Cicerone said we could take greater initiatives in the area of climatic change.

Thank you, Mr. Chairman.

Senator BAUCUS. Thank you very much, Dr. Schnittker.

Dr. Bruck?

STATEMENT OF DR. ROBERT IAN BRUCK, DEPARTMENTS OF PLANT PATHOLOGY AND FORESTRY, NORTH CAROLINA STATE UNIVERSITY

Dr. BRUCK. Mr. Chairman and members of the committee, I appreciate the opportunity to appear before you today to testify on behalf of S. 2666 before the Senate. This bill significantly moves toward the reduction of manmade pollutants in our atmosphere. Its authors should be proud of this accomplishment.

My name is Dr. Robert I. Bruck, and I serve on the faculty of both plant pathology and forestry at North Carolina State University in Raleigh. I would like to briefly share with you some 6 years of personal experience, conducting research on the effects of atmospheric deposition on the high altitude boreal montane ecosystems of the southern Appalachian Mountains.

New evidence supporting the premise that unprecedented forest declines have taken place throughout central Europe and the high altitude portions of the eastern United States has been accumulated, principally over the past 10 years. Several researchers have reported significant decreases in annual ring increment growth of several tree species in remote areas of the eastern United States.

A systematic decline of red spruce has been documented quantitatively in the Green Mountains of Vermont, the Adirondacks of New York, and the White Mountains of New Hampshire, as well as Virginia, North Carolina, and Tennessee. In the northeastern United States, standing dead red spruce trees account for approximately 22 percent of the spruce present, and an additional 40 percent of the spruce is showing symptoms of dieback. This mortality is directly correlated with elevation.

Surveys begun in 1983 on Mt. Mitchell, North Carolina, and six other southern Appalachian peaks, indicate that red spruce and, to a lesser degree, Fraser fir, exhibited marked growth reduction beginning in the early 1960's. Surveys had also indicated that visual forest decline symptomatology was occurring throughout the southern Appalachian Mountains. West-facing slopes appeared to have increased decline and dieback incidents along with greater ring suppression, which was observed on over 82 percent of all red spruce trees, both dominant and co-dominant, that were sampled. A rapid deterioration in the physical appearance of the Appalachian spruce-fir ecosystems seems to be in progress.

In recent decades, emissions of acid deposition and photochemical oxidant precursors—e.g., sulfur and nitrogen oxides—have increased the exposure of extensive forest areas in both central Europe and eastern North America to these substances and to their photochemical oxidant products. Reports of decreased growth and increased mortality in these high elevation areas, receiving the highest rates of atmospheric deposition, have increase scientific efforts to quantify changes in forest productivity and to identify these causes.

The potential synergistic nature of combined pollutant exposure and the range of direct and indirect effects make quantification of the observed effects particularly challenging. The complexity of forest growth processes and the sensitivity of forest trees to natural environmental stresses add to the difficulties in being able to specifically quantify pollution effects.

I have submitted to you written testimony addressing the quantitative measurements of atmospheric deposition and the numerous in situ effects observed in our studies on Mt. Mitchell. Through the research of the EPA Mountain Cloud Chemistry Program, we have learned that deposition of strong acids via cloud interception by trees, combined with prolonged exposure to high ozone episodes, in and unto themselves form an area of great environmental concern.

The fact that these high elevation forests are also exposed to high concentrations of gaseous and liquid phase hydrogen peroxide, volatile organic carbon compounds, greenhouse gases, and heavy metal deposition, creates a very complex scenario that amounts to a "chemical soup" which these forest ecosystems must either adapt or succumb to. Although many greenhouse and laboratory experiments have been conducted to address the potential effects of single air pollutants under controlled environmental conditions, detecting responses in mature forest trees is made extraordinarily difficult by several factors, including the complexities of succession, competition, pests, pathogens, climate, and site-specific factors, and the potential interactions between acid deposition, gaseous pollutants and trace metals, and the lack of unaffected control ecosystems.

At the present time no experimentally reproducible definitive proof exists that acid deposition or its precursors are currently limiting the growth or condition of forests either in Europe or the United States, due to the complexities addressed above. The standard forest pathology tenets of Koch's postulates that have been used by my profession for more than 100 years perhaps have little or no validity in assessing these in situ situations that are presently occurring in the high altitude systems of eastern North America.

It is the contention of this scientist that the scientific and policymaking communities will have to find common ground in dealing with imperfect knowledge for the purpose of making important assessments as to whether or not mitigation and control should be implemented in reducing anthropogenic pollutant deposition to these ecosystems. Although the research information that is procured by scientists must continue to be funded, using research as an excuse to forestall creative and fruitful dialogue leading to sound mitigation strategies is foolhardy at best and dangerous to the future of terrestrial ecosystems at worst.

The deposition of atmospheric pollutants to the eastern spruce-fir ecosystems often occurs at acute levels. The chronic deposition of manmade air pollutants on these fragile and unique ecosystems perhaps points to the spruce-fir forest as a indicator of potentially more serious and widespread decline phenomena.

It is my belief that in our society, being as wise and far-sighted as we would like to believe we are, if we are to err, we need to err on the side of preserving and protecting our natural resource base. We are then faced with the dilemma of having to ameliorate the insulting agents in our environment many years before we have definitive proof as to cause and effect. Is there a choice?

In closing, I would hope that the various sectors—State, Federal, and private—of our society will come together in understanding that the protection of our environment is more than just an economic or a political issue, but rather an ethical and moral issue—as stated by my colleagues previously before this committee—that needs to be addressed in an objective and scholarly way to preserve this planet in at least as good a condition as we inherited it.

Thank you, Mr. Chairman. That concludes my statement.

Senator BAUCUS. Thank you very much, Dr. Bruck.

Dr. McLean?

STATEMENT OF DR. DEWEY M. McLEAN, DEPARTMENT OF GEOLOGICAL SCIENCES, VIRGINIA POLYTECHNIC INSTITUTE

Dr. McLEAN. Thank you, Mr. Chairman. I have been asked to discuss the effects of climatic warming on mammalian adaptation and extinctions.

For the past 2 million years, mammals have spent most of their time in cool, ice age conditions, and relatively short periods in warm times known as interglacials. Today, we live in a relatively hot interglacial world. There is much evidence that mammals do not function well, reproductively, in modern high environmental temperatures, and this is prior to the onset of any potential greenhouse warming. I will cite some examples taken from my written testimony.

In Arizona and Missouri, cattle conception rates in the cool months are about 50 percent, but in the hot months drop to about 20 percent, or lower. For Florida cattle, as environmental temperatures increase from about 70 to 95 degrees Fahrenheit, conception rates drop from 40 to about 30 percent. And humans are not immune from the effects of high environmental temperatures. In much of the world there is a marked drop in human conception rates in hot summer months.

How it is that high environmental temperatures affect conception rates has been identified by dairy science reproductive physiologists. It involves females. High temperatures cause overheating in female mammals. As a defense against overheating, the animal's blood flow is shunted to its periphery to carry its body heat to the environment. This reduces the flow of blood to the uterus which creates a problem for a developing embryo. Uterine blood flow is a developing embryo's source of oxygen, water, and nutrients, and hormones, and also serves to carry metabolic heat away from the embryo.

An embryo must be maintained at a nearly constant, optimum, temperature. However, high environmental temperatures cause the female's internal temperature to rise. A rise of about 2.7 degrees Fahrenheit of the female's internal temperature will kill most embryos. Lower temperatures can cause damage such as dwarfing, skeletal abnormalities, and fetal malformations, et cetera.

The environmental temperatures that cause overheating to begin are about 85 to 90 degrees Fahrenheit, and lower in high humidity. Here is the problem that we face in any greenhouse warming. Because embryos require a nearly constant temperature, and because high environmental temperatures cause females to overheat, rapid greenhouse warming could impose severe adaptational problems for many mammals.

I spend much time integrating the past with the present. By doing so, I believe I now have enough information to predict how rapid climatic warming would affect modern mammals. We could expect reduction in population numbers caused by embryo failure, in which large mammals would be more affected than would small ones. There would be wide scale dwarfing, and skeletal abnormalities, and middle and high latitude mammals would suffer more than would tropical mammals. This is because of the polar amplification of warming, and also because in the middle latitudes the cool winter months are the prime breeding season, and greenhouse warming causes greater wintertime than summertime warming. This would reduce the prime breeding season at the higher latitudes.

These predictions work for the last time the Earth heated up—about about 11,000 years ago, at the end of the last Ice Age. At that time, there were global mammalian extinctions in which large mammals were most affected. Dwarfing occurred on a global scale, and skeletal abnormalities occurred in some genera. The extinctions were most severe in high and middle latitudes. North America, as an example, was hit with especial severity, losing about 70 percent of its large mammals.

In conclusion, today, we live in a hot world in which many species already experience reproductive problems in high environmental temperatures. Any significant greenhouse warming would increase reproductive problems that would likely track, and expand in scale with, the warming. The middle latitudes where we live could be hit especially hard.

Thank you.

Senator BAUCUS. Thank you, Dr. McLean.

Dr. Weiskel?

STATEMENT OF DR. TIMOTHY C. WEISKEL, HENRY LUCE FELLOW, HARVARD UNIVERSITY

Mr. WEISKEL. I am trained as an anthropologist, and I was asked to comment on the middle range, between years and decades, and the last 2 million years in some sense.

It is not entirely true that we are facing unprecedented circumstances. While Vice President Bush indicated recently, concerning the beach pollution this past summer, that 1988 was the year that the environment began to talk back, in reality the environment has been talking back to man for centuries, indeed millenia. What is striking in retrospect is our seeming inability or our stubborn refusal as a culture, and perhaps even as a species, to hear what it has been saying.

The message we should have heard is simple. All civilizations depend ultimately on the ecological viability of their primary productivity—that is, their agricultural base and their forest regeneration. Those cultures whose ecosystems function so as to destroy topsoil, squander fossil water, or deplete plant genetic resources, are destined over time to experience either permanent dependence on other cultures or certain and sudden ecological decline on their own.

The environmental archaeology of ancient civilizations makes this dramatically apparent. Agricultural societies of the ancient Near East frequently reached population densities that exceeded the capacity of their land to produce food on a sustainable basis. Problems of overgrazing, watershed deforestation, soil erosion, siltation, waterlogging, soil salinization, and crop blight emerged as the permanent hallmark of these ancient civilizations. The dynamic involved in the rise and fall of ancient societies contained an irreducible ecological component.

Since the discovery of the new world, in ecological terms, predatory expansive agriculture and parasitic resource use have characterized European civilization, leading some emergent cultures such as our own to believe in the mythology of "expanding frontiers." It is important to realize that increases in agricultural output over this period, however, were accounted for not so much by improvements in basic technology as they were simply by the overall expansion of the land surface under cultivation.

While total production rose dramatically in the last 400 years, productivity per acre and productivity per energy unit of input has actually declined. In the modern world, we are the best at producing things at the worst ratios—ratios of inputs to outputs. It is as if Europe, having expanded upon the things of nature, came to believe that expansion was in the nature of things. It is not.

The European experience of overseas expansion and the ensuing pattern of industrialization has engendered deep-seated habits of thought and images of cultural self-perception. In our day, these images and mental metaphors leave the industrial world very poorly equipped to construct a viable system of stable production on our finite planet.

We heard Senator Reid say earlier, many of us are hearing things today which we would not like to hear. I would add that we may not even be capable of hearing them, for our cultural categories are predicated on expansion. We need urgently to reassess our circumstance. In effect, we are trying to sustain a frontier culture in a post-frontier world. Little wonder our environmental policy is so embarrassingly immature.

Simply put, we need to learn that ultimately there are no frontiers in an ecosystem. Moreover, no one element in an ecosystem can continue to grow infinitely. To pretend otherwise will simply contribute to the system's overall instability and eventual collapse. Our circumstance can be summarized rather quickly in graphic terms that I have prepared for use with the testimony that I have submitted, and you can follow those graphs from your seats.

This first graph depicts what is called carrying capacity and, generally speaking, population. It is really population times resource use. We don't know how far apart they are, but we do know that at least in local circumstances carrying capacity is declining, and again in global circumstances population is increasing. The problem is, we don't know how far apart they are.

The trend, however, is clear. Carrying capacity and population are approaching one another. What isn't clear is what will happen as they approach one another. Here cultural variation is considerable. What happens as things get more complex in the environment is not entirely encouraging. Both individuals and cultures seem to have a threshold of the complexity they can absorb. As things move from the left to the right on the bottom scale, things become more complex in an environment, there seems to be a peak to the amount of information that individuals and societies can absorb about their own circumstance.

Even more discouraging, as ecological stress increases, again there seems to be a threshold beyond which cooperation is demonstrable. After a certain level of ecological stress, the cooperation that was characteristic of earlier social interaction degenerates, often into open conflict.

The result is that there are two ultimate scenarios that we are facing, in broad and very general terms. One is one of adjustment, where a society both perceives and cooperates in time to avert the excess of population times resources over the carrying capacity.

The other scenario, I am afraid, is what is referred to as overshoot and collapse. This may be where a society either fails to perceive or fails to cooperate. Either one of those conditions not being fulfilled, as it were, can lead to this circumstance. Again, I would argue that this is not unprecedented in human history. It is the rule in agricultural societies, to overshoot and collapse.

What we are facing in American agriculture and in the expenditure of fossil fuels in American agriculture is a rapid recipe for collapse, in this respect: We are spending more and more energy to produce one calorie of food than we have—than any society has—in human history.

In addition, we are reaching the point of what scientists would refer to as diminishing return. That is, you can put more energy in on the bottom of this scale, on the X axis, that is, energy into the food system can be put in more and more, but the corresponding output is not coming back. We are "S"-ing out, if you want, in this respect. The production curve is leveling off. This means that future production increases in food are going to be very energy expensive, precisely at the time that we are running out of that nonrenewable resource.

Now what I would argue for here is—perhaps the most pressing ecological problem, not in years but decades—is to move from a petro-intensive agriculture to ultimately a biosustainable agriculture. If we don't do it, our collapse, I am afraid, is going to be rather dramatic. The reason for this is simply that more and more countries and populations of the world have come to depend upon the surpluses of a breadbasket here in the United States, and we have predicated the production in that breadbasket more and more on fossil fuels.

The combined impact of those two thrusts is to lead to rapid decline when either the fossil fuels decrease or the whole system experiences the kind of perturbations that we have heard documented so dramatically here in climatic terms. If you shift the locus of where dry and wet belts are in the world agricultural system, you don't have the flexibility to react to changes in the time that we are going to need to act.

Thank you very much.

Senator BAUCUS. Thank you all, very, very much. This is very provocative testimony. Most of you were not here to testify as to the causal relationship between the greenhouse phenomenon and the adverse consequences that you are describing. That is, forest fires occurred in part because of the drought, that is, the dry conditions, but Jim, you are not here to say in your professional judgment whether or not that is caused by the greenhouse phenomenon. Dr. Schnittker, you are talking about world food, grain reserves and surpluses, and addressing how that is changing because of drought conditions. The same with you, Dr. McLean and Dr. Weiskel, on how higher heat conditions adversely affect mammals.

I still would like to know, nevertheless, in your judgment as human beings, as people who study, as professionals in your specific areas, do you tend to think or do you tend not to think that the adverse consequences that you have described are caused or are not caused by the greenhouse phenomenon that we have been discussing today? Gentlemen, do you any of you have any views on that? Mr. Overbay?

Mr. OVERBAY. I guess I am going to have to hedge on that answer, too, in that we really don't have that strong of evidence. We do have evidence, of course, that we have had these periods of drought in the past and we have had these catastrophic fires in the past, so it may be a little bit early to say that the greenhouse phenomenon is what is causing this. However, we can certainly predict that if we continue to have problems with drought and with warming, we are going to continue to see these same kinds of effects on our national forests.

Senator BAUCUS. Dr. Schnittker?

Dr. SCHNITTKER. I lean towards the view of cumulative effects having some adverse consequences on agricultural production, but with sort of erratic results, and we don't know just where they are going to happen.

Senator BAUCUS. What about the causes of the dry conditions, the drought? Do you have any feeling about that?

Dr. SCHNITTKER. I think the greenhouse effect is certainly involved, but it may also be simply weather effects which would have occurred in any case.

Senator BAUCUS. Okay. Dr. McLean?

Dr. MCLEAN. I consider a greenhouse in a longer term perspective. I can't say that there are any effects of warming at this stage on mammalian faunas that we could recognize. However, I read in the paper recently that some dairy farmers said that, because of the current hot summer, they could expect lower production in terms of births of their livestock, but I have seen no numbers on it.

I am addressing the future, if a major greenhouse develops. We have clear evidences, documented, and reproducible in the dairy science laboratory, that heat does hurt, and it operates by killing embryos. If we let the Earth heat up rapidly by several degrees Celsius, we will cause problems for ourselves. As I see it, mammalian bio-evolution can go in one direction, and it is all bad for us.

Senator BAUCUS. Dr. Bruck and Dr. Weiskel, do you think there is a greenhouse phenomenon that is causing these adverse consequences you have described?

Dr. BRUCK. Yes. I think it is very important to recognize the fact that we simply have a change in jargon, in my opinion. For 10 years we have been talking about acid rain and atmospheric deposition as perhaps affecting one or more components of our ecosystems. The fact is, when you take it right down to the roots, when you burn fossil fuel you are producing carbon dioxide. All the other components of greenhouse gases are part of the petrochemical industry generation. The fact is, that is all one and the same, and whether or not we can actually separate out one phenomenon from another, whether or not it is atmospheric deposition in terms of ozone, in terms of acid rain, in terms of global climate change or other VOC's in the environment, I really believe that we are looking at one giant phenomenon that is influencing many of our natural ecosystems.

Senator BAUCUS. Dr. Weiskel?

Dr. WEISKEL. Well, I am not qualified as a meteorologist to say this, but it would be a response that the increase in global carbon and the apparent surface temperature heating has implications far beyond whether temperatures are changing. Independent of whether the mean annual temperature of the entire "ball of wax" is changing, large surfaces of the Earth can go in and out of agricultural production.

It is very sobering for an anthropologist to realize that most of the world's food systems have been put into place since 1945, in what meteorologists consider a very exceptional period in climate history. If we revert to anything like the norm in climate history, we are going to have massive starvation, as we are seeing now in the Bangladesh floods—25 million people not only out of their homes but out of all productive activity in agriculture.

I am afraid that one would have to say, err on the side of caution, as our natural scientists have been saying. We need to build in margins of stability, if we are not going to have massive reversals in the amount of people who die, the diseases that break out, and the political instability that will ensue from all of that.

Senator BAUCUS. Well, that is a good point. I guess the question is the difference between a false positive and a false negative. That is, if our premise here is false and we still proceed to try to control the greenhouse phenomenon, the consequences may be adverse but they are not as adverse if we are wrong, that is, if we don't proceed and the problems are that much worse.

That really gets to the point of whether the worst premise is false or not. That is kind of a theoretical question, but is science—I would address this to the earlier panel, too, who I see in the audience, this is particularly addressed to the scientists—is science progressing to the point where a greater percentage of the theories that are worked out turn out to be true and accurate with subsequent empirical data, experiments, or not?

Earlier in history Aristotle thought that the sun revolved around the earth. Newton said no, and Einstein developed his theories, and I think basically his theories of relativity have been proved out, basically. I am wondering now whether there is a greater probability that theories are more accurate now than not, just as a very general principle. I know it's hard to answer, but if one of the scientists could just very, very briefly touch on that.

Dr. BRUCK. Mr. Chairman, I think that you hit a very important word, and that is "probability." I have stated before in testimony and in writing, that if we are looking for definitive empirical proof of many of the things you have heard in testimony today, you are going to be waiting for a long time, if not forever. The fact is that we must take an epidemiological approach to these problems, look at mechanisms, look at causes, and come up with a probability that in fact the hypothesis is true, and then act on that.

Senator BAUCUS. Yes, but in our scientific community, are theories more likely than not to be generally borne out to a greater degree? I am just curious if anybody can address that question, or is there just no way to predict that? I don't mean to confuse this, but I am sort of reminded of another principle. I must apologize to all of you. I just finished reading Steven Hawking's book, "A Brief History of Time," and it gets into the second law of thermodynamics and enthropy and disorder and so forth. So I am just curious, in your judgment, are we progressing so we can more accurately predict consequence or not? Dr. Wunsch?

Dr. **Wunsch**. In general terms, of course, science progresses. Weather forecasts are today better than they were 20 years ago. We can expect they will get no worse, and probably better, over the next 20 years.

Science tends to progress when theories are shown to be demonstrably wrong. That is when you get a revolutionary advance, and you have to distinguish these things.

I think the likelihood that we would have been as confident 30 years ago in sitting here and saying what we are seeing are greenhouse like phenomena, is much lower. We would not have been willing to do that.

What we are all saying is, we are not prepared to say what we are seeing are greenhouse phenomena. I think what we are saying with some confidence is that we are seeing greenhouse-like phenomena; that if we are right and the greenhouse is coming, you are going to see more and more of these things. The chances that we are wrong in this list we have been giving, that these things will not happen, is very small.

Senator **Baucus**. Thank you very much.

Senator Chafee?

Senator **Chafee**. I would like to follow up on that, if I might. I see Dr. Rowland, Dr. Wunsch, and Dr. Cicerone are still here. Here is my question, yes or no, and I know that is not the favorite type of answer that either politicians or scientists like to give. Here it is: Hurricane Gilbert, a hyperhurricane now registering five, is this consistent with global warming or isn't it? Yes or no. Dr. Wunsch.

Dr. **Wunsch**. I would say that it is exactly the type of thing that we expect to see under greenhouse warming.

Senator **Chafee**. Dr. Cicerone? Dr. Rowland?

Dr. **Rowland**. That converts to a yes.

Dr. **Cicerone**. I don't know.

Senator **Chafee**. Record hot weather throughout the United States and the world, consistent with global warming?

Dr. **Wunsch**. Yes.

Dr. **Cicerone**. Yes.

Senator **Chafee**. The drought in the Great Plains, consistent with global warming?

Dr. **Wunsch**. Yes.

Mr. **Cicerone**. Yes.

Senator **Chafee**. High levels of smog and other air pollution? I saw some pictures of the air pollution that Dr. Bruck has from the top of Mt. Mitchell, is that consistent with the greenhouse effect?

Dr. **Rowland**. I would say there that it is more regional effect. If there were no greenhouse effect, he might still lose his forests because of local pollution.

Senator **Chafee**. Monsoon flooding in Bangladesh, consistent with greenhouse effect?

Dr. **Wunsch.** Increased incidence of coastal flooding is one of the consequences of the sea level rise.

Dr. **Weiskel.** That seems to be, as well, tied to a pattern of decades of forest degeneration. That is, the Himalayas have been deforested for a while, and what we are getting is a run-through of the system of rain that used to be kept on surface or in ground water reserves.

Senator **Chafee.** Because in the Himalayas they have cut down so many trees?

Dr. **Weiskel.** Right.

Senator **Chafee.** Well, as I see it, we have crop failures and forest fires and hurricanes and monsoons and dying forests, and it seems to indicate that the greenhouse effect is here. I find the most telling testimony we have had today was when, I believe it was Dr. Wunsch, and indeed the entire panel, agreed that it is going to have disastrous effects. We just don't know when, but it is going to happen. It seems to me the challenge for us is to make plans right now as if it is going to happen within the shortest possible period.

I thought this was an interesting panel. I must say we don't get many anthropologists here before this committee.

Dr. **Weiskel.** There was a call for greater social science work. I would add to the spectrum of economics, which usually gets in there, a little focus on what has happened either in other cultures currently facing the problems or in past civilizations.

Senator **Chafee.** I'm not sure what you meant by saying that all agricultural systems in the world, now stem from post-World War Two. What did you mean by that?

Dr. **Weiskel.** No. I'm sorry. Most of the agricultural production in the world has been put in place on an infrastructure that has been constructed since World War Two, either the irrigation systems or the petro-intensive systems in the United States, and in terms of accounting for the percentage of people eating food in the world—the percentage of that output that comes from agricultural surplus created since 1945—we have a clear majority.

Senator **Chafee.** Would that statement apply to the People's Republic of China, for example?

Dr. **Weiskel.** A great deal of it, yes, because their agricultural modernization in the late fifties and sixties put in entirely new infrastructures in certain areas that are now, in fact, the subject of considerable concern for ecologists, because it appears that soil erosion rates in those areas are disturbingly high.

Senator **Chafee.** Thank you, Mr. Chairman. Thank you for assembling this gathering.

Senator **Baucus.** Senator Durenberger?

Senator **Durenberger.** Yes, Mr. Chairman, thank you very much. There are a lot of questions to ask.

I would like to use the occasion to ask Mr. Overbay how long it will take to restore the ecological system that was present in Yellowstone Park before the fires broke out.

Mr. **Overbay.** If you're talking about the restoration of those stands to the condition that they were in before the fires, it is going to take more than 100 years, although the vegetation will recover much quicker than that, but it will be different. In some ways it will be a young, healthy, growing forest rather than an older, diseased forest, but it will be different.

Senator DURENBERGER. Has the Forest Service any estimates as to what it would have cost to suppress the fires before the widespread damage was done?

Mr. OVERBAY. Normally we expect to spend approximately $100 to $125 million a year in suppressing fires. Our current estimate for this year is that the cost will exceed $300 million.

Senator DURENBERGER. But has anybody analyzed the Yellowstone situation and said, "If we had spent or had to spend X millions of dollars, we could have prevented X amount of the damage."

Mr. OVERBAY. We haven't looked at that specifically from that standpoint. I think what we need to recognize is that it isn't just a question of how much is spent on fire suppression, but what is done in terms of managing fuels. Yellowstone Park was left in its natural condition, of course. There was no manipulation of any of those fuels, so that conditions were ripe to happen, as was the case on the national forests.

Senator DURENBERGER. So we were burning natural fuels?

Mr. OVERBAY. We had a situation where the forests were mature and over-mature, essentially lodgepole pine. A lot of the forest had been damaged by mountain pine beetle, with as many as a third to one-half of the trees were dead, so we had a lot of dead, dry fuel that was continuous. With the drought conditions and the severe weather conditions, when the fires started they became very large. They generated their own energy, and there isn't a lot we can do to put those kinds of fires out, unless the fuel type changes or the weather conditions change.

Senator DURENBERGER. What is the percentage of Yellowstone that you expect to lose before the fire is exhausted?

Mr. OVERBAY. The last few days we have had a change in the weather. There has been some precipitation that has occurred there. The crews are making some real progress on those fires. Currently close to 50 percent of the park has burned. It is certainly our hope that no more of that park will be lost, but it is going to depend really on whether we get more severe weather or not.

Senator DURENBERGER. Thank you.

Senator BAUCUS. Thank you, Senator Durenberger, and thank you, all the panelists, for helping us move forward to try to find a solution to this problem. Thank you all very much. We appreciate your coming, the time and attention you have taken. Thank you.

[Whereupon, at 12:30 p.m., the subcommittees adjourned, subject to the call of the Chair.]

[Statements submitted for the record and the bill S. 2666 follow:]

TESTIMONY OF PROFESSOR F. SHERWOOD ROWLAND, Department of Chemistry, University of California, Irvine, to Senate Committee on Environment and Public Works, September 14, 1988

Stratospheric ozone depletion by chlorofluorocarbon gases (CFCs) has been a major environmental concern since the publication 14 years ago of the first outline of the problem by Mario J. Molina and myself. For most of the subsequent time, this "Rowland-Molina hypothesis" of chlorine damage to ozone in the stratosphere has been considered by many to be "controversial", although close observation has disclosed that the controversy has been a moving target as more information has been gained and various objections have been shown to be without merit in the atmosphere itself. During the past six months, a very strong scientific consensus has developed which essentially accepts without reservation that chlorine atoms can and do cause the depletion of stratospheric ozone. These gases released to the atmosphere by man are the primary cause for the massive, rapid losses of ozone over Antarctica which has occurred in the southern spring throughout the 1980s. However, this consensus about the damaging role of the CFCs does not mean that all uncertainty has disappeared. Scientific uncertainties continue, and questions about the magnitude of the future effects of CFCs upon stratospheric ozone must still receive answers listing broad numerical ranges for the possible effects.

Some aspects of the CFC-stratospheric ozone problem have been generally accepted as true for about a dozen years, and the U.S. federal ban on the use of chlorofluorocarbon gase as the propellants in non-essential aerosol sprays was first announced in October 1976. One aspect on which there now is substantial numerical agreement is the long lifetime of the CFCs in the atmosphere because of their inertness against chemical reactions in the lower 98% of our surrounding blanket of air. The atmospheric residence times of CFC-11 (CCl_3F) and CFC-12 (CCl_2F_2) were originally estimated by Molina and Rowland as 40 to 80 years, and 80 to 150 years, respectively. Currently, actual measurement in the atmosphere provides estimates of about 75 years and 120 years for these two gases. The chief implication of these residence times measured in centuries is that the world will have to live with any of the environmental consequences for the next 200 years.

Although a strong consensus now exists that chlorine from the CFCs is actively destroying stratospheric ozone, predictions of future depletions of ozone by CFCs are as uncertain as they have ever been. The major underlying cause for this continuing uncertainty is the confirmation both in the laboratory and in the atmosphere that heterogeneous chemical reactions play a critical role in facilitating ozone depletion. Some of these reactions occur during the long polar night on the icy surfaces of polar stratospheric clouds (PSCs), converting chlorine from its non-reactive temporary reservoirs HCl and chlorine nitrate into molecules such as Cl_2 and HOCl which are very sensitive to sunlight. These and other reactions transform the gaseous nitrogen oxides into nitric acid, and leave it sequestered on the particle surfaces in the PSCs. The first sunlight of the approaching Antarctic spring releases the chlorine, and virulent chain reactions proceed for five or six weeks because the NO_2 needed for the normal chain-breaking reaction with the radical ClO cannot occur. These reactions are clearly occurring over Antarctica, and major ozone depletion is certainly taking place, with the loss of as much as 95% of the ozone in some layers of the lower stratosphere, and as much as 60% of the ozone in the total vertical column. However, despite the certainty of these observations, the ability to predict the magnitude of future ozone losses remains highly uncertain.

The most serious obstacle to predictions of future ozone depletion lies in the quantitative aspects of heterogeneous chemical reaction rates. This uncertainty can be illustrated as follows. When I proposed in early 1986 that heterogeneous reactions of chlorine were potentially important in the Antarctic and could be the key to the Antarctic ozone hole, a frequent response was to say that they could not be quantitatively important because the efficiencies of collision of these chlorine species with the icy particle surfaces would only be about one in a million--that only one surface collision of a molecule of chlorine nitrate or HCl would actually result in chemical change. A series of brilliant experiments by Dr. Mario Molina and his collaborators at the Jet Propulsion Laboratory has shown that the "conventional wisdom" of efficiencies of one part per million were seriously in error, and that chemical reactions occurred for perhaps one collision in ten. The knowledge that these reactions are about 100,000 times more rapid than believed by many only two years ago is evidence of the great uncertainty in the input data needed for accurate quantitative predictions of future levels of ozone depletion.

The semi-quantitative problem has been solved--collision efficiencies of one in ten are fast enough to make heterogeneous reactions important in the stratosphere, and chemical analysis over Antarctica shows the changes taking place implied by heterogeneous chemistry--very low levels of nitrogen oxides, changing chlorine distributions, etc., in the Antarctic polar vortex. For accurate quantitative predictions, however, the efficiencies need to be known with a precision of a few percent; ranges of one in five to one in twenty to one in one hundred are not good enough. Furthermore, these efficiencies need to be known for crystals of the precise structure existing in the PSCs, under the same conditions of the Antarctic stratosphere with about one-tenth the surface pressure and temperatures of -90°C (- 130° Fahrenheit). The scientific community is already discussing three types of PSC, and the efficiencies for each reaction will need to be known on each of these types of cloud, and for the mixture of particles intermediate among them. Even the formation of such crystals in the laboratory will be very difficult for these conditions, let alone carrying out precise, highly-reproducible measurements of the reaction rate constants of the surface-reactive chlorine nitrate and HCl. Even if these rate constants were successfully measured with such precision sometime in the next one or two decades, the same questions would then have to be answered for Arctic PSCs (Is their composition the same as for the Antarctic PSCs?); for the background aerosol particles, largely believed to contain sulfuric acid and water, which exist in the stratosphere at all latitudes; and for the volcanic clouds thrown into the stratosphere on an irregular basis. The atmospheric models are capable of demonstrating that the heterogeneous reaction rates measured in the laboratory are in the correrct ranges to explain the large ozone depletions observed over

Antarctica; they cannot because of the uncertainties in input data work the problem in the reverse direction with sufficient precision to make accurate quantitative predictions of future ozone depletions, either regionally or globally. Our policy decisions about stratospheric ozone depletion now, and for a decade or more into the future, must be made without good quantitative guidelines of what the future holds for us.

Current Levels of Ozone Depletion

The best current estimates of ozone depletion are found from a careful combination of the results from two separate observation systems: the ground-based network of Dobson instruments which provides good coverage of the north temperate zone for the past 25 to 30 years; and the global coverage by the Nimbus-7 satellite with its TOMS and SBUV instruments since November 1978. Day-to-day comparisons of individual ground stations as the satellite passes overhead permit identification of potential data problems from the ground observation system. Selected ground stations with "good" observations can then be used to measure the slow degradation of the satellite systems during their ten-year exposure in space. This drift, primarily from the degradation of the diffuser plate used for in-flight calibration, has resulted in about a 3.5% change in the ozone readings from TOMS and SBUV over the period from 1978 to 1987.

The best current evaluation of changes in total ozone have been given by the NASA Ozone Trends Panel, whose Executive Summary was announced last March 15. I have attached to my testimony a copy of the Chapter Summary of Chapter Four, "Trends in Total Column Ozone Measurements" as it appears in NASA Reference Publication 1208, August 1988. In the latitude belt

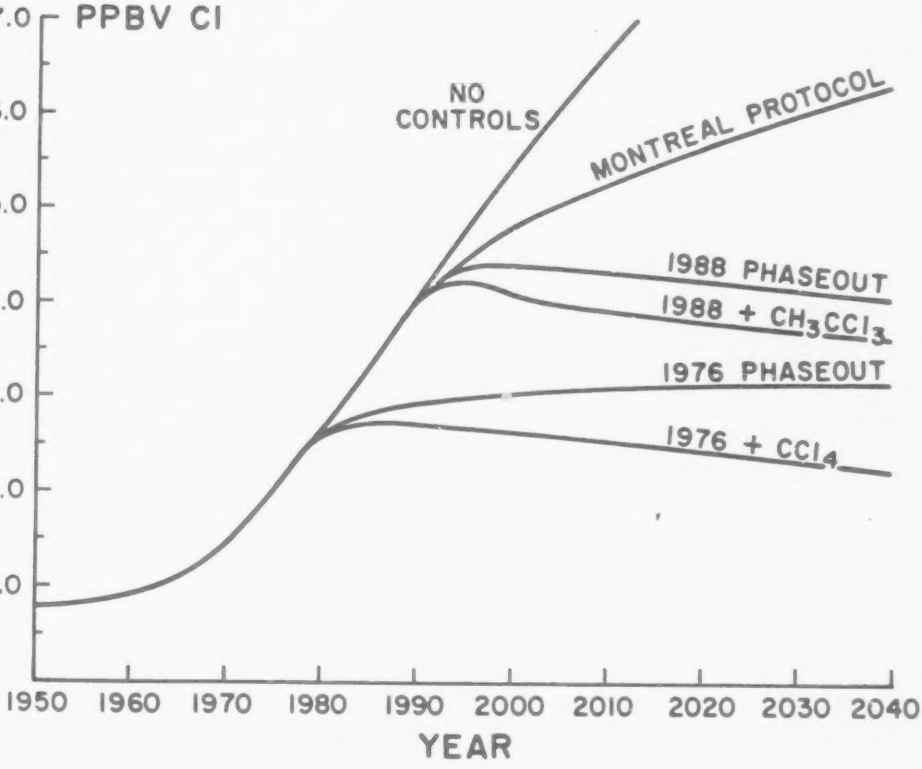
(40°-52°N) containing the northern part of the United States, the average ozone concentration has decreased about 4.7±1.5% over the past two decades in the wintertime, 1.9±0.7% in the summer; and 3.0+0.8% in the yearly average. The losses in the latitude belt (30°-39°N) for the southern half of the U.S. are about 2% in the annual average, while the largest decreases measured by the ground-based station are the wintertime losses in the northernmost band (53°-64°N) which averaged 6.2±1.7% since 1970. The satellite data, after calibration from the ground, show negative changes in ozone at all latitudes from 65°S to 65°N between November 1978 and November 1987. The largest losses were registered for the high latitudes of the southern hemisphere, and the indicated global average loss between 53°S and 53°N latitudes in this 9 year time period was 2.5±0.6%. All longer term measurements confirm a small response (1%-2%) in total stratospheric ozone to the 11-year solar sunspot cycle, which is now rising from its minimum in mid-1986 toward an expected peak in 1991. For the present several years, losses in ozone from CFCs are partially masked by an increase in ozone from the solar cycle; after 1991, decreases in ozone are expected from both. The losses in stratospheric ozone are also partially masked by the increases in tropospheric ozone, essentially from "smog" reactions both in urban communities and more generally over larger regions. These reactions contribute about 1% *more* ozone now than they did 20 years ago, so that the ozone decreases indicated above represent still larger changes in the stratosphere.

The Montreal Protocol of September 1987 for the Control of CFCs

The Montreal protocol calls for reductions in the release of CFCs to the atmosphere of 20% in 1994 and an additional 30% in 1999 relative to the emissions in 1986. If the release of CFCs were to continue at current rates, the amount of chlorine in the troposphere would continue to increase by about 1 part per billion per decade toward a level of about 5 ppb in the year 2000, 6 ppb in 2010, etc. The current level is about 3.6 ppb, twice the 1.8 ppb present in 1974 when the effects of CFCs on stratospheric ozone were first discussed. The Montreal protocol would not reduce this rate of increase very much during the next decade, and then would cut it by half during the 21st century--but it would still be an increase, reaching 5.6 ppb by the year 2020. If a total phaseout of CFC emissions were accomplished globally over the next decade, then the chlorine concentrations would peak at about 4.4 ppb around the year 2000, and then slowly decline, reaching 4 ppb about the middle of the century. (If the controls on CFCs announced in the U.S. in 1976 had been global and called for a total phaseout, the peak chlorine concentration would have been about 3.1 ppb.)

The most significant omission from the Montreal protocol is the molecule carbon tetrachloride, for which the atmospheric concentrations are moving slowly upward, not as rapidly as for the CFCs, but definitely toward higher concentrations. Carbon tetrachloride formerly was an important cleaning fluid in the U.S. and Europe, but has been displaced from such usage by other compounds because of its local hazards. In western countries, its major use now is as a precursor molecule in the chemical manufacture of CFCs. However, carbon tetrachloride appears still to be released in important quantities in eastern Europe and should be covered by the Protocol.

The attached Figure shows the effects on tropospheric chlorine of two possible additions to the phaseout proposals: a ban on carbon tetrachloride, which would lead to a more rapid reduction in total chlorine than a ban on CFCs alone; and a ban on methylchloroform. This molecule, with the formula CH_3CCl_3, is widely used as a degreasing agent, and is released to the atmosphere at a level of about 500 kilotons per year.



Its atmospheric lifetime is short, about 7 years, because of reactions in the lower atmosphere, and its stratospheric threat is much less than from the CFCs. Nevertheless, it currently contributes somewhat more than 10% of the total chlorine in the atmosphere. If it became desirable to reduce the chlorine content of the atmosphere rapidly, then methylchloroform is almost the only current contributor which could respond quickly. About 0.4 ppb of chlorine could be removed in about 20 years by a ban on the release of methylchloroform to the atmosphere.

As indicated earlier, future levels of ozone depletion are very difficult to predict because of the uncertainty caused by the necessity for inclusion of heterogeneous chemical reactions in the numerical models. In general, however, these depletions are going to follow the total chlorine concentrations in the atmosphere, for which accurate measurements and reasonably accurate predictions of the consequences of regulatory actions can be made. The Montreal protocol is not sufficient to halt the rapid increase in atmospheric chlorine content which has occurred over the past 20 years, and more extensive regulation is necessary. A complete phaseout of CFCs by 1998 appears to be feasible, but will require strenuous activity toward global regulation, and toward the development of substitutes for the current uses of CFCs. The race for such substitutes is under way, and some of the early results are promising. I also urge the addition of carbon tetrachloride to the list of chlorine-containing compounds for which global regulation is necessary under a strengthened version of the Montreal protocol.

Chapter 4: Trends in Total Column Ozone

C-4.1 Introduction

Total column ozone measurements with the ground-based Dobson ultraviolet spectrophotometer began in the 1920s, and were extended toward global coverage during the International Geophysical Year in 1957-1958. Additional programs were also begun then with ground-based filter ozonometers, whose basic principle of ozone measurement through differential comparison of the absorption of two or more wavelengths of ultraviolet light is similar to that used in the Dobson instruments. As a consequence, time series of ozone measurements are now available covering various segments of the past 30 years from more than 100 ground stations, with continual data over the past 24 years from almost half of them. These data sets are the only ozone data available which extend for time periods longer than the 11-year solar sunspot cycle, and are therefore the only data which can be used for assessing any long-term changes or trends in total ozone concentrations over a period of two decades or more. The ground-based data from the stations with longer Dobson records have been carefully assessed and reanalyzed to account especially for instrument calibration changes over this extended time period. Various consistency tests were also applied to the data, leading to the rejection for present use of some data sets because of questionable quality. The filter ozonometers were improved 17 years ago, and the data recorded with them since 1972 has been utilized in some parts of this assessment.

The quantity of reliable ground-based observations from stations in the tropics and the Southern Hemisphere is sparse by comparison with those north of 30°N latitude. Estimates of possible trends in ozone concentration in regions south of 30°N latitude -- with the exception of Antarctica -- are therefore far less precise than for latitudes between 30°N and 64°N. The reanalyzed Dobson data are not adequate for determinations of changes in the total ozone column during the past three decades over latitude bands for the tropics, sub-tropics or the Southern Hemisphere.

Since 1978, total ozone measurements have been made both with upward pointing ground-based instruments and by downward-looking instruments on satellites. The existence of two systems for measurement of the concentrations of ozone provides the opportunity for intercomparisons and calibration of their results. The major questions concerning data taken with instruments not accessible to periodic checking and recalibration during more than nine years on a satellite are whether the sensitivity of the instrument for the detection of ozone has remained unchanged over that period, and whether corrections can be made for such changes if they have occurred. On the other hand, the major problems with the ground-based data are concerned with the relative sensitivities and stability of different instruments operated and calibrated by various national agencies in locations all over the world. The intercomparison of ozone data taken by satellite instruments with measurements taken by ground-based instruments during overpasses which are nearly simultaneous in time and coincident in geography has provided very valuable checks on both types of data. Taken together, the combination of satellite instruments for daily global coverage and ground-based instruments for regular long-term calibration of the satellite systems has provided detailed global ozone coverage over the time period since 1978. Because the chief problem of ozone measurement from a satellite is one of long-term degradation in its sensitivity over a decade, its values recorded on any given day are quite consistent with one another, and furnish an excellent check on ground stations through comparison of the daily overpass results with the data reported from the latter instruments. In this manner, the satellite instruments can serve as a transfer standard for judging the degree of consistency in the results reported from all of the ground-based stations on a daily basis. Over a longer period of one to ten years, the satellite data recorded while passing over ground instruments accessible for regular checking and recalibration permit evaluation of the magnitude of any year-to-year change in the sensitivity of the satellite instrument toward total column ozone measurement.

C-4.2 Total Column Ozone Changes Since 1960 Derived from Ground-Based Data

The potential long-term precision (at ± 2 sigma) of the Dobson ozone spectrophotometer is estimated to be ±1% in the annual means, based on standard deviations from the mean analysis of individual stations. Its accuracy is strongly dependent on the quality of the calibration and operation of the instrument, as well as on the ability to assess environmental changes (e.g. an increase in tropospheric ozone). The ozone data can only be retroactively reevaluated through the availability of systematic calibrations. The precision of the reevaluated data from a "good" station is estimated to be better than 0.7% per decade. The World Primary Standard Dobson Instrument is periodically recalibrated under favorable conditions at Mauna Loa, Hawaii, and has exhibited a precision of ±0.5% over the time interval from June, 1972, to July, 1987, and can be further connected to calibrations performed in 1962 with a precision of ±1%. The precision and accuracy of another individual instrument is dependent upon their particular history and frequency of recalibration.

The total concentration of ozone in a vertical column through the entire atmosphere has long been known to vary in coincidence with several natural cycles. In addition, theoretical reasons exist for believing that total ozone may also vary in response to the activities of man, especially from the stratospheric injection of nitrogen oxides during the nuclear bomb tests of the late 1950's and early 1960's and from the release to the atmosphere of long-lived gases such as the chlorofluorocarbons (CFCs), methane, carbon dioxide and nitrous oxide. The largest natural cycle is the seasonal variation each year which produces late winter or early spring maxima in total ozone in temperate locations, and ozone minima in late summer or early autumn. The second well-established natural cycle is the variation in total ozone in concert with the quasi-biennial oscillation (QBO) in equatorial stratospheric winds, which reverse their direction approximately every 26 months. A third natural source of variability is the change in total ozone with the 11-year solar sunspot cycle. There might possibly also be variations in ozone concentrations in response to other irregular cyclic phenomena such as the El Nino Southern Oscillation (ENSO) or sporadic events such as volcanic eruptions. The rates of the ozone-removing chemical reactions involved in the NO_x and ClO_x catalytic chains are well-determined from laboratory experiments. However, stratospheric chemical reactions are complex enough to make highly desirable verification through observation of any actual effects of modifications of these catalytic chains upon ozone concentrations in the atmosphere.

C-4.3 Comparison of Ozone Data over Two Consecutive 11-Year Solar Cycles

The ozone data from the ground-based Dobson stations have been analyzed by a direct approach through comparison of the average total column ozone measurements over two consecutive 11-year solar cycles, i.e. 1965-1975 and 1976-1986, inclusive. Averaging over successive 11-year periods effectively eliminates ozone variations attributable to the natural cycles because each period includes one solar cycle, five QBO cycles, and 11 yearly cycles. The measured ozone changes between these two periods do not represent any test of the structure for the time dependence of any variations, and could be the result of increases in the abundance of trace gases, primarily the CFCs, or in part to long-term fluctuations in natural phenomena. Because there are theoretical indications that man's activities might produce winter/summer differences in ozone trends, and because earlier examination of the long records from several north temperate Dobson stations had indicated apparent winter/summer differences in the magnitude of observed ozone changes over time, the data have been considered both in terms of yearly averages and in seasonal averages during the winter-spring ozone "season" of strong westerly circulation (December through March) in the lower stratosphere, and the "summer" (May through August) easterly regime. Because the theoretical calculations in this assessment were performed for only three summer months (June through August), the observational data have also been averaged for this three-month period. The measured ozone changes recorded in these averages over these successive 11-year periods are given in Table C-4.1 for 24 Northern Hemisphere Dobson stations. These ground-based measurements of total column ozone show an average change of -1.4±0.7% for 1976-1986 in comparison to 1965-1975 in the latitude zone between 30°N-60°N. This decrease was not uniform throughout the year, but was larger in winter, -2.5±1.0%, and smaller in summer, -0.5±0.6%. The winter-time decreases were also largest at the higher latitudes.

Model calculations of the expected changes in total column ozone from an increase in the abundances of the trace gases between these two time periods do predict greater depletions at mid and high latitudes during the winter than in summer. For the summer months, the calculated changes in ozone (-0.2% to -0.6%) from the models are similar to those indicated by the ground-based observations, but calculated decreases are less than half as large as those observed during the winter period in the middle and high latitudes. The range of calculated changes in total column ozone found with these different atmospheric models over these winter months varied between -0.4% to -0.6% at 30°N and -0.9% to -1.1% at 60°N latitude.

C-4.4 Statistical Analysis of Ground-Based Data

A statistical analysis of the ground-based ozone data from the Dobson stations has been made to assess the quantitative importance of the individual natural cycles and of the atmospheric nuclear tests, and to determine the magnitude of any remaining variations which exist in the measured ozone values after 1970. Analyses seeking any such non-cyclic trends have been made in previous statistical evaluations, as well as in this assessment, to determine whether the accumulation in the atmosphere of trace gases, especially the CFCs, has been accompanied by any non-cyclic changes in total ozone concentrations. In the multiple regression statistical analysis performed here, the potential ozone changes have been described by individual monthly trend coefficients rather than by uniform trend coefficients equally applicable for all twelve months. The one-dimensional atmospheric models used for more than a decade provide global average values for ozone concentrations at each altitude, and provide estimates only of smooth yearly trends in any changes in these values. These 1-D models do not provide, for example, any estimate of variations in trends in ozone concentrations with latitude or season. The use of monthly trend coefficients, adopted because of the apparent winter/summer differences in the magnitudes of observed ozone changes, has the effect of testing hypotheses of possible

Table C-4.1

Changes in Average Total Ozone Concentrations, as Measured at Individual Dobson Stations over the 22 Year Period, 1965-1986, Inclusive.

(Percentage Differences for 1976-1986 Compared to 1965-1975.)

North Latitude	Station	Winter[1]	Summer[2]	Annual
74.7	Resolute (Canada)	- 1.4±1.8[3]	- 0.8±0.9	- 1.6±1.0
64.1	Reykjavik (Iceland)	- 2.5±2.2	+1.7±1.3	+0.1±2.4
60.2	Lerwick (Scotland)	- 3.8±2.0	- 0.9±0.9	- 1.6±1.0
58.8	Churchill (Canada)	- 4.2±0.9	- 1.4±0.8	- 2.5±0.7
53.6	Edmonton (Canada)	- 4.7±1.3	+0.8±0.9	- 1.8±0.8
53.3	Goose Bay (Canada)	- 2.4±1.3	- 0.1±1.1	- 0.8±0.9
51.8	Belsk (Poland)	- 3.2±0.8	+1.2±1.0	- 1.2±0.9
50.2	Hradec Kralove (Czech.)	- 4.7±2.0	+1.1±0.9	- 1.8±1.1
47.8	Hohenpeissenberg (FRG)	- 1.8±1.7	+0.2±0.9	- 1.0±0.9
46.9	Caribou (Maine, US)	- 2.8±1.5	- 0.6±0.8	- 1.8±0.9
46.8	Arosa (Switzerland)	- 3.0±1.3	- 1.1±1.0	- 2.0±0.9
46.8	Bismarck (N. Dak., US)	- 3.0±1.2	- 1.4±1.0	- 2.0±0.7
43.8	Toronto (Canada)	- 1.3±1.2	- 1.3±0.8	- 1.2±0.7
43.1	Sapporo (Japan)	- 0.6±1.4	- 0.1±0.9	- 0.3±0.6
42.1	Vigna di Valle (Italy)	- 2.9±1.2	+0.7±0.9	- 0.9±0.9
40.0	Boulder (Colorado, US)	- 3.9±1.3	- 3.1±0.7	- 3.3±0.8
39.3	Cagliari (Italy)	- 2.5±1.7	- 0.7±1.1	- 1.1±1.2
36.3	Nashville (Tennessee, US)	- 1.8±1.4	- 3.3±0.7	- 2.4±0.8
36.1	Tateno (Japan)	- 0.7±1.6	- 0.5±0.8	- 0.4±0.7
31.6	Kagoshima (Japan)	+0.9±1.7	+0.5±1.0	+0.9±0.8
30.4	Tallahassee (Florida, US)	- 1.7±1.9	- 0.2±1.1	- 1.3±1.4
30.2	Quetta (Pakistan)	- 1.1±1.6	+0.1±0.8	- 0.7±0.8
25.5	Varanasi (India)	- 0.3±1.4	+0.4±0.9	- 0.2±0.9
19.5	Mauna Loa (Hawaii, US)	- 1.5±1.7	0.0±0.6	- 0.9±0.6
	30°N to 60°N	- 2.5±1.0	- 0.5±0.6	- 1.4±0.7
	40°N to 60°N	- 3.0±0.9	- 0.4±0.5	- 1.6±0.6
	30°N to 39°N	- 1.2±1.5	- 0.7±1.0	- 0.8±1.1

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[1] Winter = Dec., Jan., Feb., March

[2] Summer = May, June, July, August

[3] Resolute is above the Arctic Circle, so that only less accurate moonlight measurements are available during actual winter. These "winter" data are the averages for the months of March & April.

ozone variations other than the simple assumption that any remaining trend must be equally applicable throughout the year.

These statistical analyses of the ground-based ozone data can be carried out through the examination of the individual results on a station-by-station basis, or by averaging the data over broad latitudinal bands. Both procedures have been applied in this study. Results have been obtained from three separate latitude bands covering the range from 30°N to 64°N. The scarcity of ground stations with long verified records makes latitudinal band averages south of 30°N less reliable. The data for these three latitude bands are shown in Figures C-4.1 and C-4.2 for the time period 1963 through 1986. Figure C-4.1 shows the variations in ozone concentrations for the latitude bands during the winter-spring (December through March) ozone season, while Figure C-4.2 displays the variations for the May through August period.

The magnitudes of the monthly linear trends corresponding to changes in total ozone since 1970 are shown in Table C-4.2 for three northern latitude zones with data from December 1964 through November 1986. Much less abundant data from time periods before 1965 have also been treated in a similar manner. Less reliable data have also been examined for the latitude band from 20°N to 29°N. A separate evaluation has also been made for the far-north band from 60°N to 80°N, using again some of the same stations included in the 53°N-64°N latitude band.

The magnitudes of the QBO and solar cycle effects in each latitude band are given in Table C-4.2. The well-known seasonal cycles are clearly present in the basic data and are not separately evaluated in the Table. The nuclear bomb test effects on stratospheric ozone were also evaluated in pre-1963 data, but have been calculated to be minimal by 1965, and were not included in the statistical evaluation of the data from 1965-1986. All of the statistical errors given in Table C-4.2 are at the one sigma level of significance.

The statistical estimates in Table C-4.2 of the magnitude and phase of the correlation of ozone change with the QBO, both of which vary significantly with latitude, are quite consistent with separate estimates obtained from satellite data. The measured response of total ozone to the solar cycle varies from small to about 2% peak-to-peak in the latitude bands, with the largest column ozone values found at the sunspot maximum in the winter of 1979-1980. The residual linear trends for individual months in Table C-4.2 have been averaged and give measurable changes in the annual average total column ozone of -1.7% to -3.0% in all latitude bands from 30°N to 64°N over the period from 1969 to 1986. The decreases are largest during the winter months (-2.3% to -6.2%, averaged for the four months from December to March), and smallest in the summer months (-0.2% to -1.9%, May through August, or +0.4% to -2.1%, June-August).

The trend coefficients for individual months were also tested for possible changes with the successive addition to the total data set of single years of data from 1980 through 1986, in effect a test of the appropriateness of the assumption of a linear trend since 1969. Most of the trend coefficients for the three latitude bands in Table C-4.2 show no important change with the addition of one to six additional years of data, although the overall tendency is toward more negative trend coefficients in 1986 than in 1980. However, the four months from April through July in the 40°-52° latitude band all show progressively more negative coefficients from 1980 through 1986. The measured ozone decreases for these months are not adequately described by an assumed linear variation with time since 1969, but have instead primarily occurred recently rather than gradually over the 17-year period, 1969-1986. An alternate statistical treatment with a non-linear function whose slope is approximately twice as large in 1986 as in 1965 provides a set of trend coefficients which

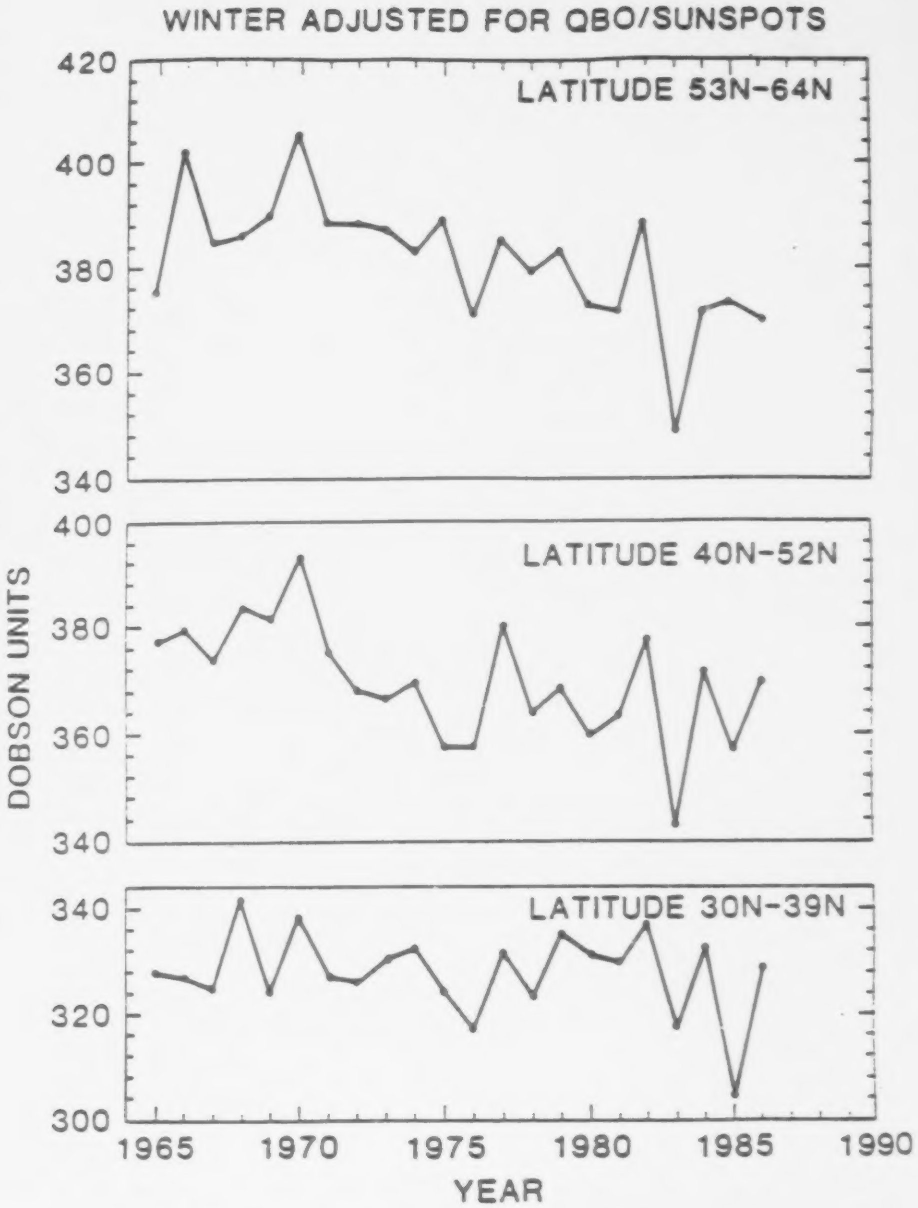

Figure C-4.1. Winter-Spring ozone concentrations (in Dobson Units) for three latitude bands in the Northern Hemisphere. (December, January, February, March; Data begin with December 1964, and end with November, 1986.) The calculated statistical contribution from the QBO and the solar sunspot cycle have been removed from the data.

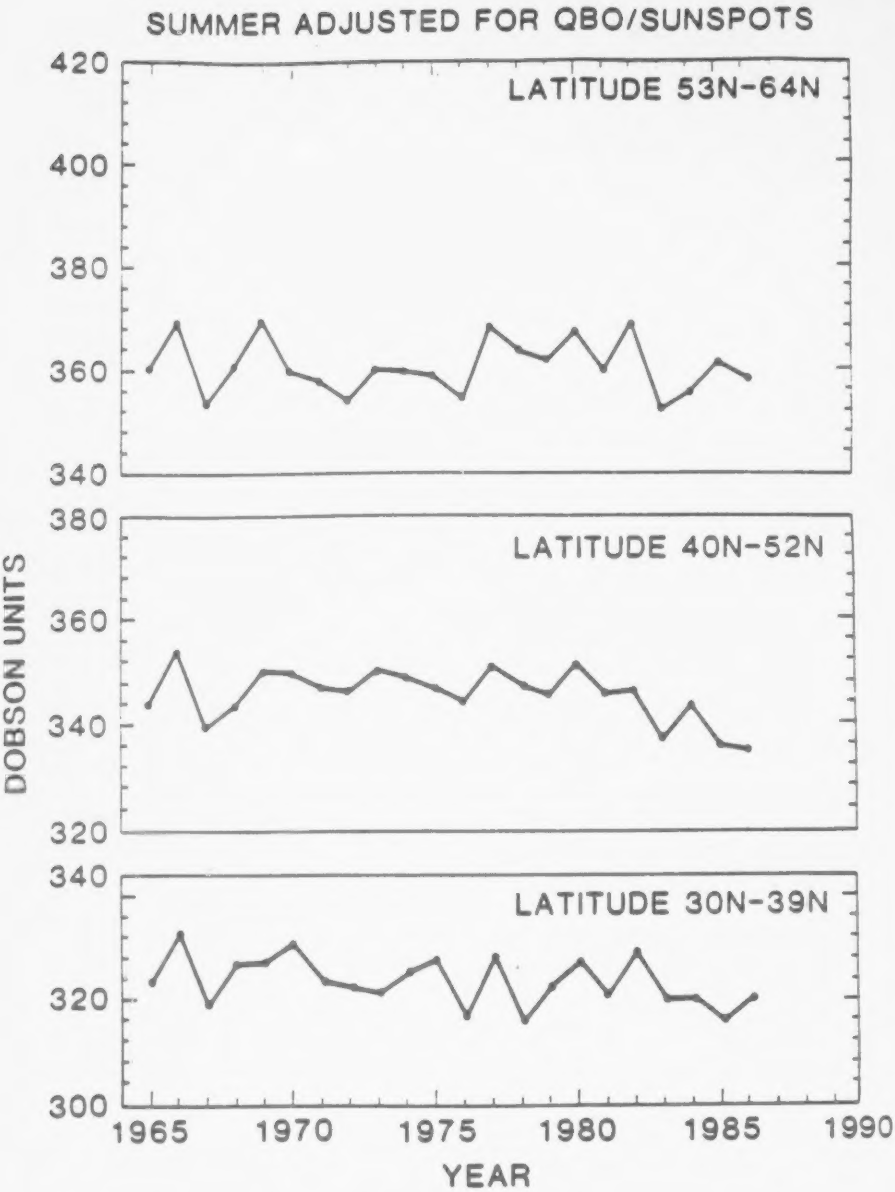

Figure C-4.2. Summer (May-August) ozone concentrations (in Dobson Units) for three latitude bands in the Northern Hemisphere. The calculated statistical contribution from the QBO and the solar sunspot cycle have been removed from the data.

Table C-4.2

Coefficients of Multiple Regression Statistical Analysis of Re-analyzed Dobson Measurements of Total Ozone Concentrations Collected into Latitudinal Band Averages. (Data are expressed in total percent changes for the period 1969-1986.)

	Latitude Band		
Month	53-64°N	40-52°N	30-39°N
January	- 8.3±2.2	- 2.6±2.1	- 2.2±1.5
February	- 6.7±2.8	- 5.0±2.2	- 1.2±1.9
March	- 4.0±1.4	- 5.6±2.3	- 3.5±1.9
April	- 2.0±1.4	- 2.5±1.7	- 1.7±1.3
May	- 2.1±1.2	- 1.3±1.1	- 1.7±0.9
June	+1.1±0.9	- 1.8±1.0	- 3.3±1.0
July	+0.0±1.1	- 2.2±1.0	- 1.3±1.0
August	+0.2±1.2	- 2.4±1.0	- 1.0±1.0
September	+0.2±1.1	- 2.9±1.0	- 1.0±0.9
October	- 1.1±1.2	- 1.5±1.5	- 0.9±0.8
November	+1.5±1.8	- 2.4±1.3	- 0.1±0.8
December	- 5.8±2.3	- 5.5±1.7	- 2.1±1.1
Annual Average	- 2.3±0.7	- 3.0±0.8	- 1.7±0.7
Winter Average	- 6.2±1.5	- 4.7±1.5	- 2.3±1.3
Summer Average (a) JJA	+0.4±0.8	- 2.1±0.7	- 1.9±0.8
(b) MJJA	- 0.2±0.8	- 1.9±0.7	- 1.9±0.8
QBO*	- 2.0±0.6	- 1.3±0.6	+1.9±0.6
Solar*	+1.8±0.6	+0.8±0.7	+0.1±0.6

* Percent changes per cycle, minimum-to-maximum. All uncertainties are expressed with one sigma statistical significance.

Average of Monthly Ozone Trends in Dobson Units per year and Percent change in 17 years (See Table C-4.2 above - annual average):

DU/yr:	- 0.52±0.16	- 0.63±0.17	- 0.32±0.14
%/17 yrs:	- 2.3±0.7	- 3.0±0.8	- 1.7±0.7

Uniform Trend in Ozone Change Assumed throughout the year, in Dobson Units per year and in Percent Change in 17 years:

DU/yr:	-0.14±0.13	-0.47±0.13	-0.17±0.11
%/17 yrs:	-0.7±0.6	-2.3±0.7	-0.9±0.6

is marginally superior to the standard simple assumption of linearity in such trend estimates.

The trend coefficients found for multiple regression analysis with the usual assumption of a single trend applicable throughout the year in comparison with the results from 1-D atmospheric models are given at the bottom of Table C-4.2 in parentheses in percent change over the 17 years from 1969 to 1986. Differences exist: (a) among the indicated trends for different seasons, and between (b) a yearly ozone change obtained as the average of the monthly trends and (c) the yearly ozone change found with the assumption of a uniform trend throughout the year. The value in Table C-4.2 from (b) is always more negative than from (c). Because the trends found in winter and summer months are usually significantly different from one another, the basic assumption underlying (c) is not a satisfactory model for northern latitude ozone data, and the regression coefficients in parentheses should be replaced by the regression coefficients for individual seasons. The underestimate of the average ozone loss in (c) relative to (b) is the consequence of the greater statistical weight given to the more precise summer data in calculating a uniform trend to the data for all of the months simultaneously. The calculation of a yearly average absolute change in ozone concentration or in percentage loss is itself somewhat artificial to the extent that the differences between winter and summer trends may reflect different underlying physical or chemical mechanisms leading to ozone variability.

The changes calculated in total column ozone with current atmospheric models as the consequence of variations in the output of ultraviolet radiation over the 11-year solar cycle are broadly consistent with the changes indicated by the multiple regression analysis. However, while the predicted decreases in total column ozone caused by the increased abundances of trace gases (including the CFCs, methane, nitrous oxide and carbon dioxide) are consistent with the observed decreases during the summer period, the mean values of observed winter-time decreases are larger than calculated in the atmospheric models.

In assessing the overall changes in total ozone concentrations, it should be kept in mind that observational balloon-sonde data suggest that tropospheric ozone concentrations may have increased in mid-latitudes in the Northern Hemisphere by as much as 1% per year over the past 20 years. Such changes in the lower atmosphere are equivalent to an increase in total column ozone of about 2%, and would appear in total ozone observations in combination with any changes in stratospheric ozone.

C-4.5 Total Column Ozone Changes from Satellite Data

The total ozone data measured by the SBUV and TOMS instruments on the Nimbus 7 satellite require independent calibration because of the slow degradation with accumulated exposure to direct solar radiation of the diffuser plate common to the operation of both. The quantitative influence of this degradation in the diffuser plate on total column ozone observations can be checked by comparison of the total ozone found during satellite overpasses of ground stations. Three separate, not totally independent procedures have been used in these satellite/ground intercomparisons. The first used a set of data from 41 Dobson stations, with no selection of the ground-based data for overall quality of the data from these stations. A second procedure has utilized the overpass data for a total of 92 Dobson and filter ozonometer stations from 1978 on, with selection of the ground-based data such that records from individual stations were eliminated when the ground data for any particular month showed excessive scatter in the overpass differences. A third method involved satellite overpasses of Mauna Loa, Hawaii, on those days during which the World

Primary Standard Dobson instrument was undergoing its regular periodic recalibration at that location. An overpass of an individual Dobson station is illustrated in Figure C-4.3 with the TOMS ozone readings for June 29, 1979, in the vicinity of the Hawaiian Islands. The circled measurement was recorded at Mauna Loa on that day by the World Primary Standard instrument. (Ozonesonde data were used to correct for the ozone amounts between the altitude of the Mauna Loa Observatory and the mostly oceanic surface sensed by TOMS.)

All three satellite/ground tests gave consistent results indicating that the ozone measurements with the satellite instruments drifted over time by -3.5±0.5% during the nine years following satellite launch in October 1978. The overpass data versus 41 stations are shown by the small dots in Figure C-4.3, while the crosses represent average values for the comparisons with the World Primary Standard at Mauna Loa during the indicated summers. Further, an independently derived algorithm for treatment of the satellite data has shown close agreement with this ground-based calibration of the satellite instruments, confirming that a drift of this magnitude was quite consistent with the known instrument properties. The choice among the various algorithms consistent with the satellite operational data has been made by accepting the ground-based comparisons as a valid recalibration of the satellite instruments.

The total ozone data accumulated with the TOMS instrument have therefore been provisionally recalculated with the assumption that the algorithm used to convert measured instrumental radiances into ozone concentrations has been systematically drifting by a total of -3.5% over the nine-year period from 1978-1987. Detailed analysis of the auxiliary satellite data is still continuing to determine whether more precise calibration data can be recovered. The drift has not been uniform as shown by the line in Figure C-4.4, and the data have been modified on the basis of specific correction factors for each month mirroring the uneven degradation over time. This normalization procedure assumes that no significant latitudinal bias exists in the drifting of the conversion algorithm with time. When calculated in this way, the normalized TOMS satellite data show a decrease of total column ozone between October 1978 and October 1985 in all latitude zones in both the Northern (-1.1% to -3.7%) and Southern (-1.1% to -9.0%) Hemispheres, as shown in Table C-4.3. The time period from late 1978 to late 1985 corresponds generally to the decline from solar maximum (December 1979) to solar minimum (summer 1986), and these changes therefore represent a combination of ozone variability attributable to inceases in trace gases and to declining solar activity. Because the satellite data do not yet include even one full 11-year solar sunspot cycle, no attempt has been made to separate these trends in the satellite data set taken alone, or to evaluate the magnitudes of the variations accompanying the solar sunspot and QBO cycles.

Data from the latitudes poleward of 53° latitude in each hemisphere are not included in the global or hemispheric calculations of Table C-4.3, but are given separately for the bands between 53°-65° in both hemispheres. No band analysis poleward of 65° has been given because of the absence of any measurements from the polar night. The differences in the zonal average ozone concentrations indicated by TOMS, after calibration to the ground-based instruments, are shown in Figure C-4.5 by month and latitude, with contour lines for every 2% difference in ozone. The data have been averaged over the years 1986 plus 1987, and 1979 plus 1980 to smooth out most of the fluctuations associated with the QBO. The large losses of ozone associated with the Antarctic spring appear in the lower right of Figure C-4.5. However, ozone decreases as large as 5% are indicated year-round as far north as 60°S, for most months to 50°S, and in mid-summer to 40°S.

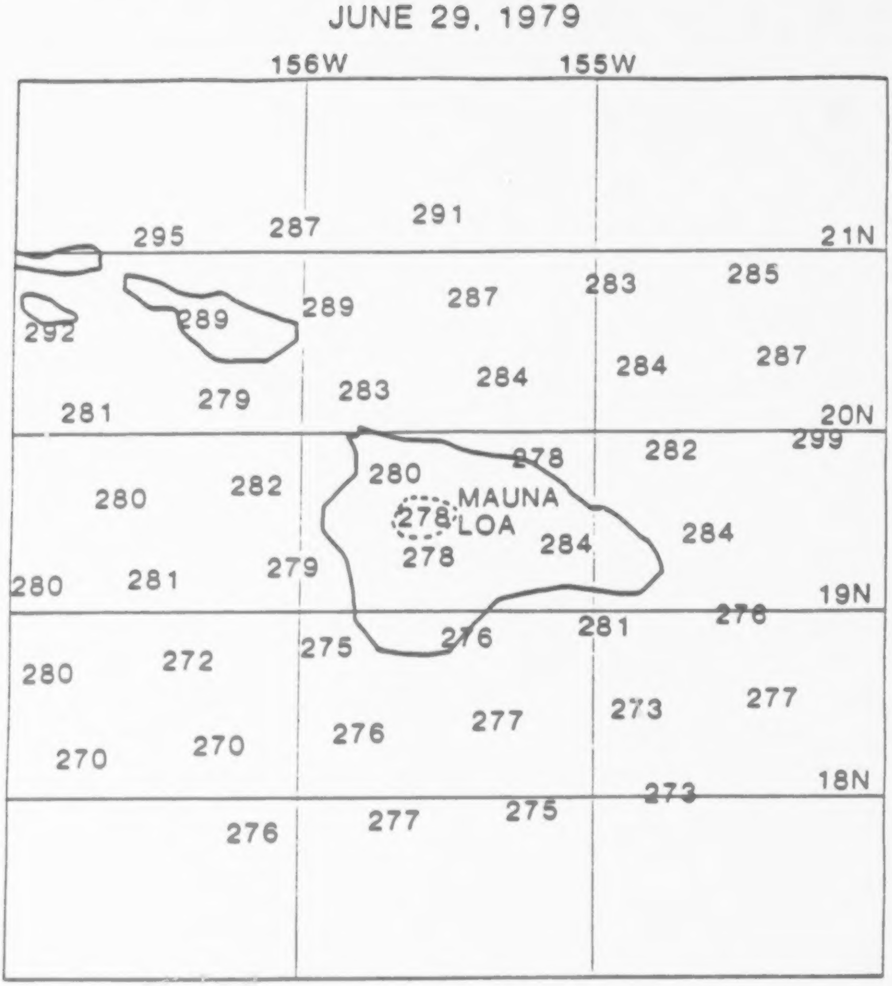
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Figure C-4.3. Intercomparison of TOMS overpass measurements of total ozone with World Primary Standard Dobson ozone measurements at Mauna Loa Observatory, Hawaii, June 29, 1979. The Mauna Loa measurement is enclosed in the broken circle.

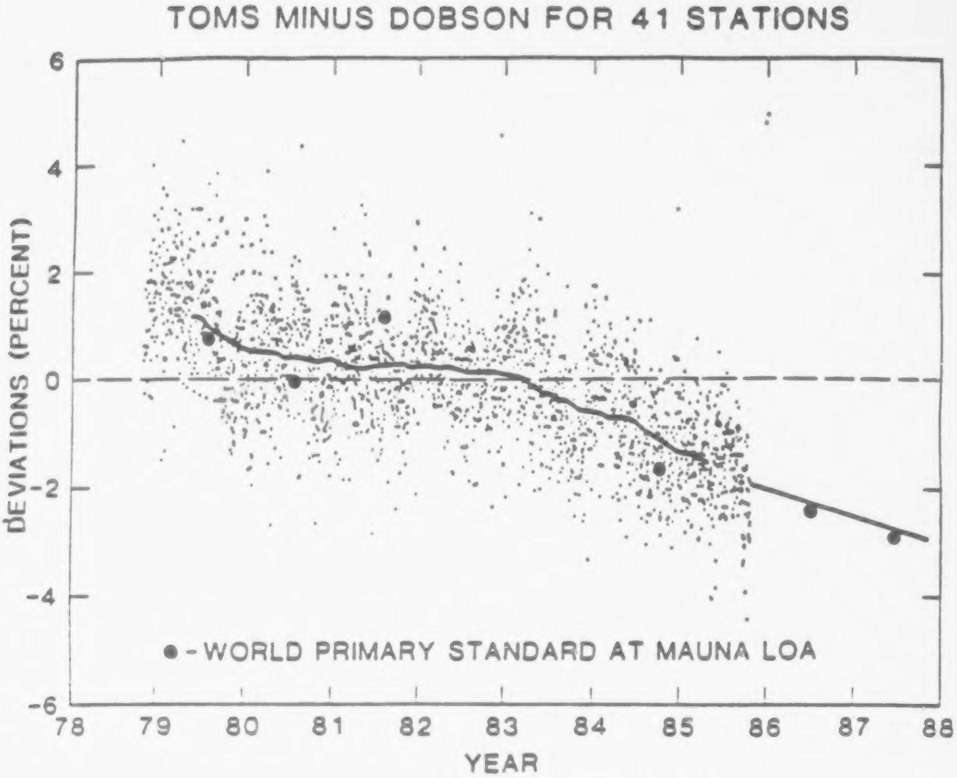

Figure C-4.4. Intercomparisons of TOMS overpass measurements of total ozone with ground-based ozone data from 41 stations (small dots) and with the World Primary Standard Dobson during summer measurements at Mauna Loa, Hawaii.

Table C-4.3

Percentage Changes in Total Column Ozone

(Measured by TOMS on Nimbus 7, Calibrated by Comparison with Ground-Based Measurements)

Latitude Band	Total Change from 11/1978 to 10/1985	From Table C-4.2 (1969-1986)	Total Change from 11/1978 to 11/1987
Global, except high latitudes			
53°S - 53°N	- 2.6±0.5		- 2.5±0.6
Hemispheric			
0 - 53°S	- 2.6±0.9		- 2.9±0.9
0 - 53°N	- 2.1±1.5		- 1.8±1.4
Bands			
53°S - 65°S	- 9.0±1.8		-10.6±1.6
39°S - 53°S	- 5.0±1.8		- 4.9±1.8
29°S - 39°S	- 3.2±2.4		- 2.7±2.1
19°S - 29°S	- 2.5±1.9		- 2.6±1.5
0 - 19°S	- 1.1±0.8		- 2.1±0.8
0 - 19°N	- 1.1±1.5		- 1.6±1.3
19°N - 29°N	- 3.5±2.2		- 3.1±1.9
29°N - 39°N	- 3.7±2.0	-1.7±0.7	- 2.5±1.7
39°N - 53°N	- 2.7±1.7	-3.0±0.8	- 1.2±1.5
53°N - 65°N	- 2.4±1.6	-2.3±0.7	- 1.4±1.4

(Linear trends with an autoregressive model through TOMS data, with uncertainties at the one sigma level of significance.)

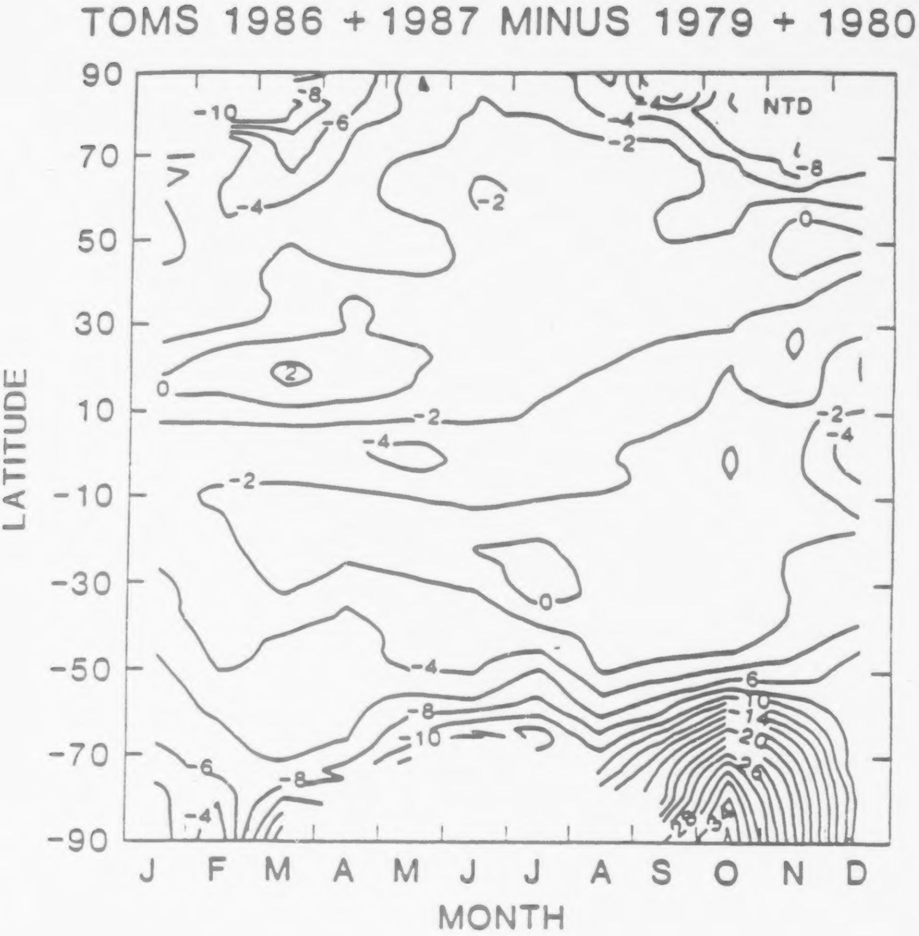

Figure C-4.5. Changes by month and latitude in Total ozone between 1979/1980 and 1986/1987 as measured with TOMS on the Nimbus 7 satellite. (Two year averages are used to minimize differences originating with the QBO.) Contour plots are given for intevals of 2 percent change. The TOMS data have been normalized to the Dobson (NTD) ground-based data as shown in Figure C-4.4. The TOMS instrument operates with sunlight scattered from the atmosphere and therefore provides no data from the areas in the polar night.

Atmospheric model calculations of changes in total column ozone from 1979 to 1985 predict a decrease representing the sum of a loss because of the increased abundance of CFCs and other trace gases, and an additional loss because of the declining phase of the solar sunspot cycle. The model calculations show a greater change in total column ozone at mid to high latitudes in winter (-0.5% to -1.5%) than in summer (-0.2% to -0.6%), while the contribution to ozone decrease from the lessening solar activity is found to be relatively the same in the models for all seasons and latitudes. The magnitude of the solar cycle variation is uncertain because of lack of precise knowledge of the variations in short wavelength solar ultraviolet emission over the complete solar cycle, and is estimated to lie between -0.7% and -2.0% from the maximum to the minimum of the cycle.

The change in total column ozone in the Northern Hemisphere predicted in the models is generally consistent with the observations over the period 1979 to 1985, although the measurements suggest that the largest changes may have occurred in the mid-latitudes while the models predict the largest changes at high latitudes. Because the models used in these calculations do not have the capability of predicting the loss of ozone associated with the Antarctic ozone hole phenomenon, comparisons of model calculations with Southern Hemispheric observations must be made only with substantial reservations about the significance of the results.

Examination of the normalized TOMS satellite data given in Table C-4.3 suggests that total column ozone in the Northern Hemisphere has increased since passing the combination of the intensive QBO of 1985 and the solar minimum in 1986. On the other hand, the decrease of total column ozone averaged over the Southern Hemisphere appears to have continued through 1987 at approximately the same rate as for 1978 to 1985. Such an observation could be the consequence of sufficient losses in ozone through the special conditions of Antarctic springtime to cancel out any projected increase in total ozone from the increasing phase of the solar cycle. The current solar cycle should peak about 1991, after which the cyclical change in ozone concentration in response to solar variability is expected again to trend downward.

C-4.6 Recommendation

The ground-based Dobson measurement system and, to a lesser extent, the filter ozonometers, play important roles in the global ozone monitoring system. They do this both through direct determinations of ozone concentrations over specific geographic locations over a long period of time, and by ground-truth calibrations of the satellite systems. While much of the data from these systems has been reanalyzed in this assessment, more accurate re-evaluations can be made by examination of the day-to-day measurements at each individual ground-based station by the various national meteorological services. With vigorous efforts to carry out such re-evaluation of data, the existing 25 to 30 year records of the ground-based stations can be made even more useful for determination of trends in ozone concentrations over the past three decades. Vigorous efforts in upgrading past data can be especially useful now and in the next few years. Such re-evaluation and interpretation of data on total ozone concentrations should involve broader participation of the scientific community than it has in previous years. Finally, the measurement of ozone on a global basis requires a truly international effort supported strongly by the various national organizations.

Senate Subcommittee on Environment and Public Works
Subcommittee on Hazardous Wastes and Toxic Substances, and
Subcommittee on Environmental Protection

Reference: S.2666 The Global Environmental Protection Act of 1988

Testimony by

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14 September 1988

1 Introduction

I have been asked to comment on observed changes in the global ocean, their possible connection to "greenhouse gas" effects, and potential consequences of such changes to the climate system. It must be understood that the global ocean is a much more difficult system to observe than either terrestrial biota or the atmosphere, and so much of what I can describe about ongoing changes is fragmentary and only suggestive. In comparison to my colleagues who are describing other parts of the Earth's physical/biochemical system, I am unable to make very many definite statements about what is happening.

Both meteorologists and oceanographers have recognized for a long time that as the greenhouse gases increased in the atmosphere, there would be changes in oceanic properties which would have to be taken into account in order to make serious predictions of how the climate system would change. That is to say, everyone agrees that if the atmosphere changes at all, there will be consequent and inevitable changes in the ocean. These oceanic changes will themselves change the atmosphere (a "feedback" phenomenon) so that accurate forecasting of the greenhouse effects obviously requires a clear and quantitative understanding of how the ocean will respond. Determining how the ocean is *actually* changing thus becomes a major element in the discussion of whether the "greenhouse effect" is "here", whether it is behaving as expected and what we should expect to happen next.

I will list below some of the changes known to me for which some evidence exists. To understand the possible implications of what we do see, a little background on the interaction of ocean and atmosphere is necessary:

Atmosphere and ocean are coupled together at the seasurface. There they exchange momentum (the wind blows on the seasurface, generating waves and setting water in motion, and thus exerting a drag on the atmosphere), and energy in a variety of forms (including exchanges of moisture through rainfall and evaporation, direct exchange of heat by conduction and convection, etc.) and a whole suite of chemical exchanges in both directions (including carbon dioxide and other greenhouse gases).

Perhaps the biggest differences between the atmosphere and the ocean are simply that water is very much heavier than air, and so the ocean moves sluggishly compared to the atmosphere; and that the heat storage capacity of water is very much larger than that of air. The sluggishness of the ocean and its large capacity for soaking up heat (as well as a variety of other physical quantities) means that the ocean contains a long-term memory of past weather and climate. It is this memory that controls much of what we know as "climate". To cite only one example, the major reason that Europe is warm compared to the same latitudes on our side of the ocean, is that weather patterns at those latitudes move largely west to east. The weather in Labrador comes from the land to the west - and land has no long term memory of the previous summer, so the air is very cold. By the time the weather has gotten to Europe, it has absorbed enormous amounts of heat from the ocean - which has retained its heat not only from the previous summer but from warming near the equator years before.

The ocean thus "remembers", and by remembering smooths out the climate extremes with time and latitude which one expects on an earth without an ocean (the much greater climate and weather extremes of our Midwest, and central Asia, as compared to regions on the coasts are an indication of how the ocean acts to ameliorate our present-day climate.)

Should there be trends in the properties of the ocean, under the greenhouse impact they will in turn influence our weather and climate. In determining what those changes and trends are likely to be one must examine several possibilities.

First, because the ocean remembers, it is an integrator over long periods and regions, of the changing thermal state of the atmosphere. If the atmosphere is truly getting warmer, the ocean too should gradually be getting warmer. But because the heat storage capacity of the ocean is so large, one certainly does *not* expect the ocean to get a little bit warmer everywhere; rather one expects any such warming to manifest itself first in those regions where ocean and atmosphere are in most intimate contact. But this does *not* mean that it is the seasurface which will necessarily show the change first. Indeed what evidence there is suggests that if a warming is taking place (see next section), it is showing up at depth. But, and this is a very important "but", the ocean remembers for a long time, and because water moves around, one may see climate changes depicted in the ocean years and decades after the atmosphere changed, in regions remote from where atmosphere and ocean came in contact. I remind the Committee of the intensely cold winters of roughly a decade ago; the ocean will retain some memory of those winters; unfortunately, exactly where and in what way is not entirely clear to us. Given the very large bulk of the ocean, it is likely that the ocean even retains a memory of the "Little Ice Age" of the 16th and 17th centuries, and hence may be still cooling in parts of the abyss, and warming up in other parts.

Second, the ocean exchanges carbon dioxide with the atmosphere, with the gas moving between the two systems, in either direction depending upon location and season. On average however, the ocean will gradually absorb a fraction of the increasing atmospheric carbon dioxide - i.e. one expects the total CO-2 in the ocean to increase over time. We do seem to see this happening as discussed later. Similarly, the imprint of the chlorofluoromethanes is clearly seen in the ocean.

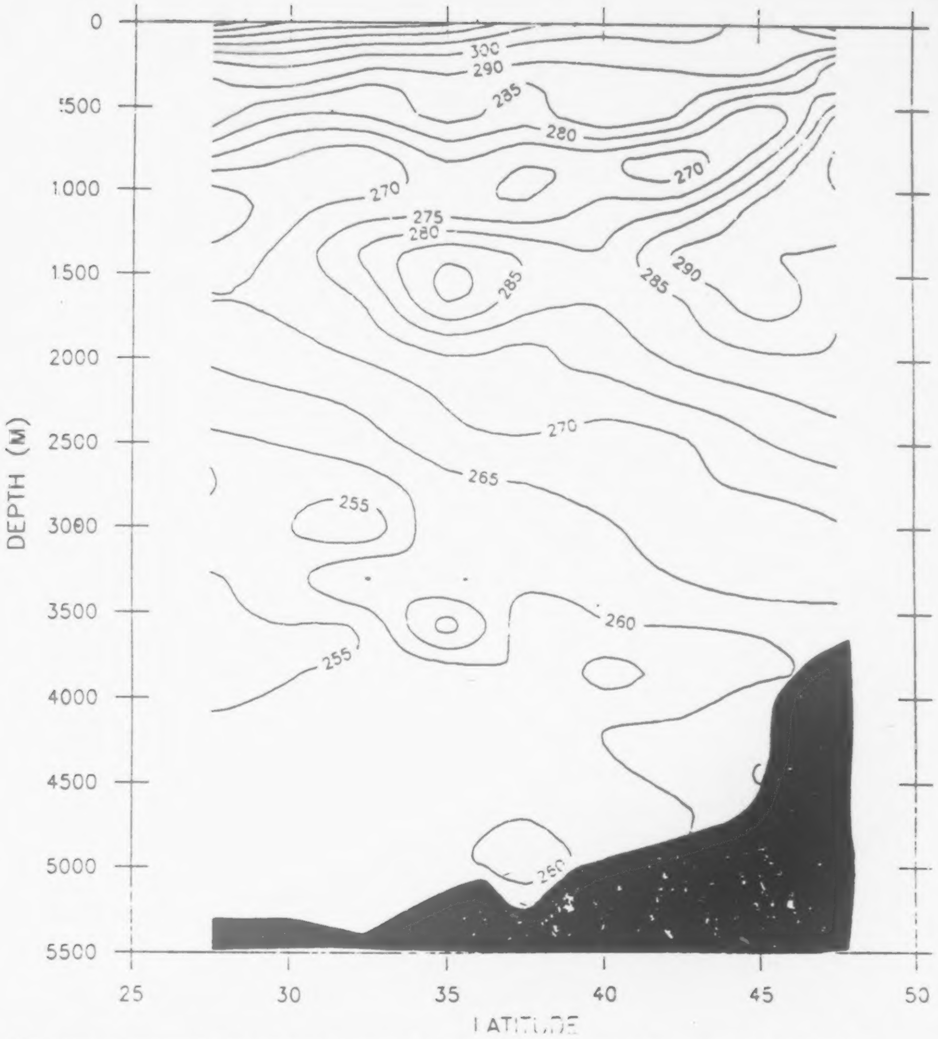
A third effect is an indirect one: if one warms sea water, it expands; thus if the ocean is getting warmer, one would expect to see a sea level rise (a rise separate from that induced by melting of icecaps and glaciers). One can seek such a rise in the historical records of sealevel, also described below.

Eventually, some effects would be expected to appear in the overall chemistry, and in a changing oceanic biology. Definite observations, apart from the changing CO2 content itself, have so far proved elusive.

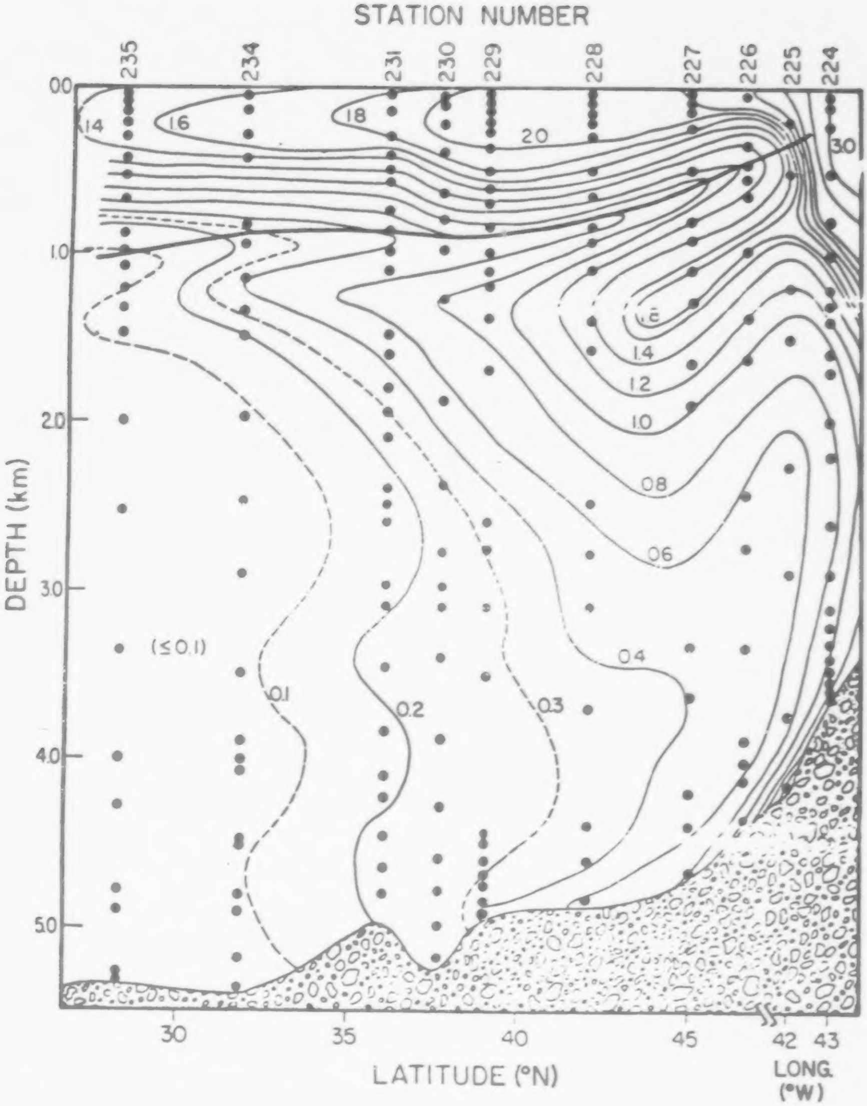
Finally, there are effects that would manifest themselves in a changing coupling between ocean and atmosphere - there are many of these: one can seek trends in wind strength over the ocean (some atmospheric models predict these will decrease overall); cloudiness over the ocean (a reflection in part of the evaporation/rainfall changes which are predicted) may show trends; the incidence of hurricanes would likely grow if the seasurface temperature is increasing. We can seek signs of these and other trends, but to cover all of them here requires too long a story.

2 What Do We See?

Figures 1 and 2 display respectively, the fields of CO2 and of one of the Freons, in seawater as seen in the North Atlantic. In the first figure, one sees the numbers increasing towards the surface of the ocean. The interpretation (Dr. P. Brewer, Woods Hole, personal communication) is that the lower values near the seabottom represent the values acquired by the water years ago when it was at the seasurface - at a time when atmospheric CO2 values were



1. Numbers representing the carbon dioxide in the ocean. The sea surface is at the top. One is looking westward, toward the United States, with the polar regions on the right. Lowest values occur near the bottom, and carry atmospheric concentrations of CO2 from many years ago when the water contacted the atmosphere. Water near the surface was in contact with the air much more recently, and carries a much higher CO2 imprint (data courtesy of Dr. P. Brewer and the TTO Program).



2. Concentration of Freons in the same locations as in the previous picture. Normal oceanic values are zero. One sees this greenhouse gas "dyeing" the ocean from top towards the bottom. (Data courtesy of TTO Program).

lower. The high values near the seasurface today reflect the increased atmospheric concentrations picked up by water in recent contact with the air. Thus one sees quite clearly that the ocean contains a graphic record of increasing CO2, and that much of this CO2 is entering the ocean. Determining how fast this is happening and whether this rate is likely to remain fixed in the future, are important issues in understanding what is going to happen to our climate.

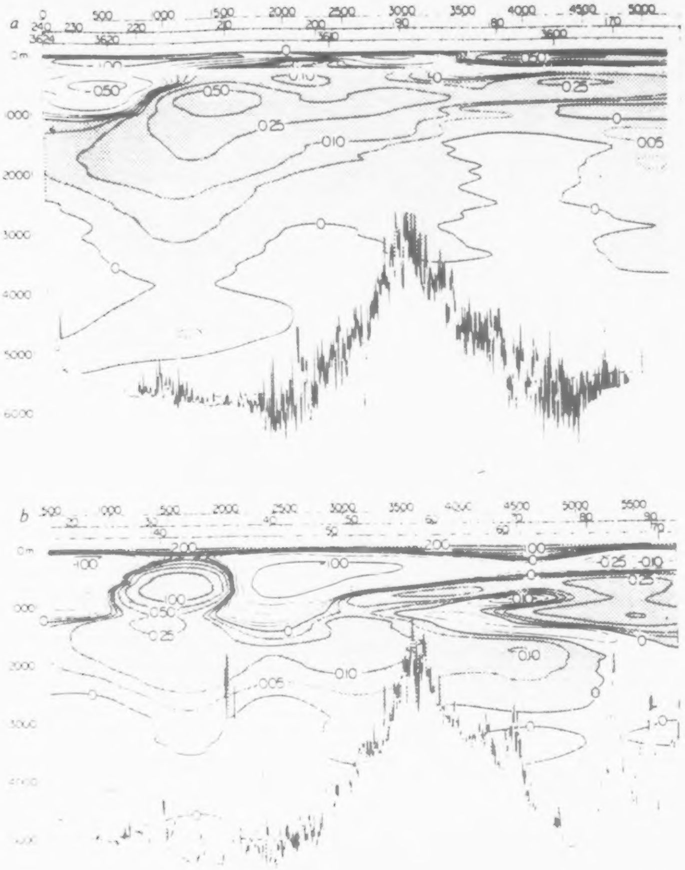
The second figure depicts the entry of the fluorocarbons into the ocean; I show this picture for several reasons. Such gases are themselves a center of environmental concern; but because they do not occur in nature, they are to the oceanographer a particularly graphic indicator of the connection between the ocean and what is happening to our atmosphere.

Figure 3 depicts an estimate of temperature changes in the North Atlantic Ocean in the 23 year period 1958 to 1981. In the lower picture, one is looking northward, with the United States near Cape Hatteras at the left, and the Straits of Gibralter on the right; in the upper picture, Florida is on the left, and Africa on the right. The sea surface is at the top in both pictures. The area of stippling is the region where the water temperature apparently *increased* in the time between the two sets of measurements. Typical values are a few tenths of a degree Celsius. On the other hand, the clear areas show a region of apparent temperature *decrease* over the same period. Notice that much of the region of decrease is close to the seasurface. How should these results be interpreted? The answer is "very cautiously".

I show in figure 4 a cartoon of how the flow of water in the North Atlantic operates. It can be thought of as a type of conveyor belt, in which warm water flows toward high latitudes, providing the heat that keeps Europe warm. The cold atmosphere sucks heat and moisture out of this northward moving branch, causing it to become heavy and to sink. As it sinks it carries with it the imprint of the rising CO2 and fluorocarbons of the atmosphere (as we see in figures 1 and 2), but also a memory of the temperature of the air with which it came in contact. If the air has warmed over the years, one would expect the water sinking to depth also to become a little warmer; thus the warming might appear first at mid-depths as we see, rather than near the surface, as one might at first expect. So why am I suggesting great caution in concluding that we are seeing the greenhouse warming?

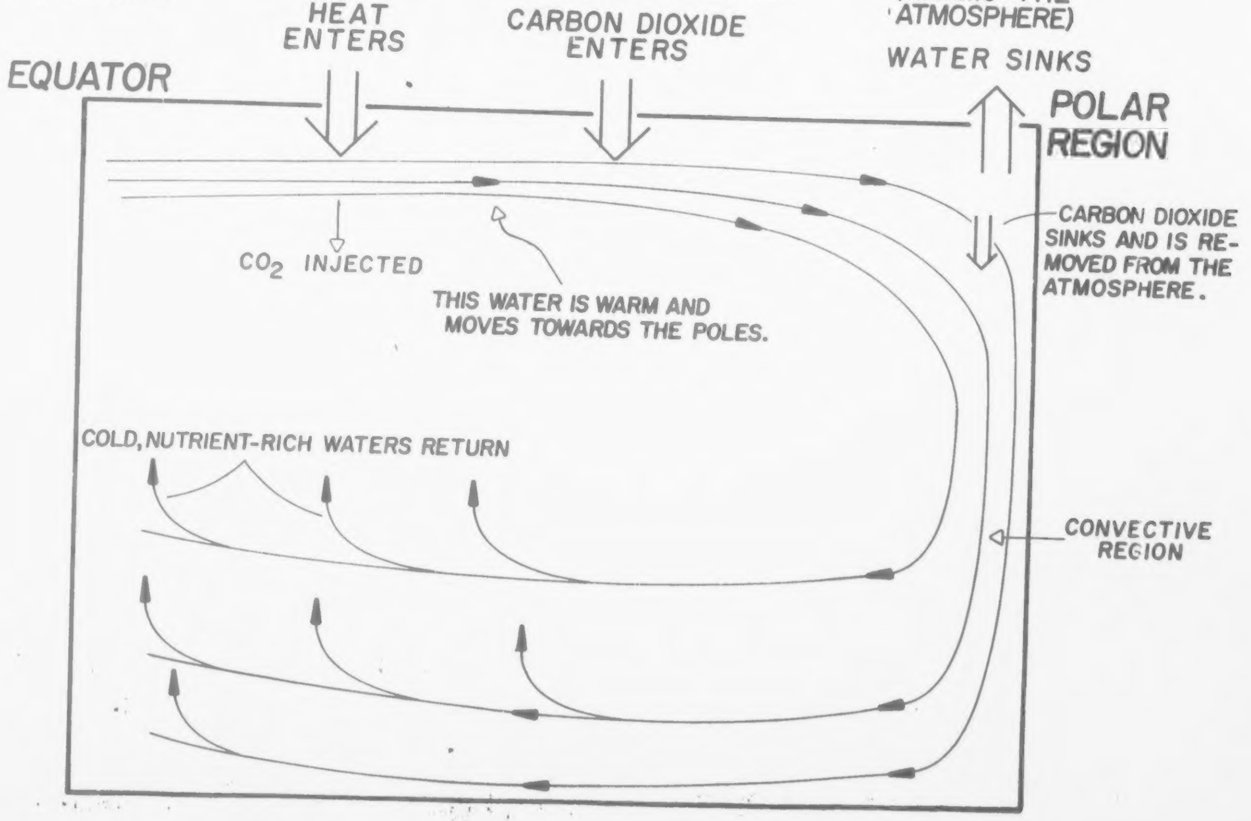
There are several reasons. The measurements are based upon two surveys taken 23 years apart. We do not know what has happened in the seven years since the latest survey: Did the the apparent warming turn into a cooling, or did it continue? We do not know whether the warming represents a long term trend that has been going on for decades prior to 1958, and if it were, whether it represents a greenhouse effect, or a recovery to "normal" conditions from some earlier episode of unusual cooling. We do not know whether the phenomenon is manifested in the global ocean, or is confined to this small part of the North Atlantic Ocean. The ocean is constantly changing; some of its changes have nothing to do with man-made effects, but are natural fluctuations of a complex fluid system. The temperature change we are seeing may well be the result of the greenhouse effect; but no one can demonstrate that these data definitely show the onset of the greenhouse effect in the ocean.

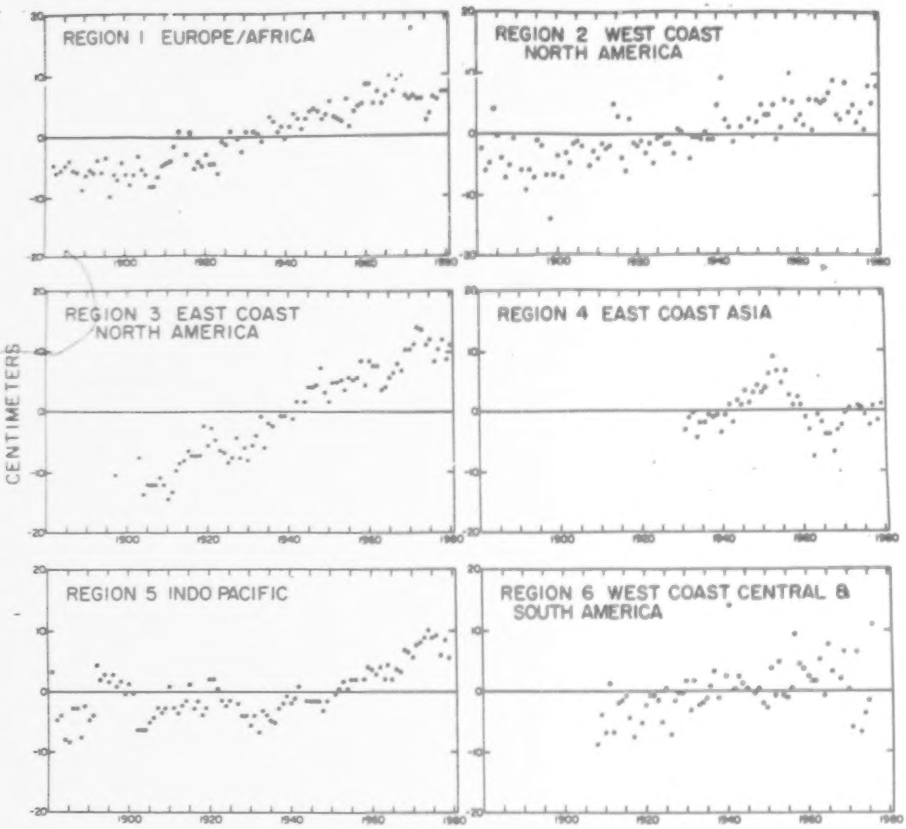
What about sea level? Figure 5 shows the trend in sealevel over large regions of the ocean. Over much of the globe, including the United States coastline, there is little doubt that we are seeing a rise in sealevel consistent with a warming of the water column plus some glacial melt. But there are other places where sealevel appears to be dropping. Of course sealevel may



3. Apparent temperature change in the North Atlantic Ocean from data collected in 1958 and in 1981. Top picture runs from near Florida to Africa and the bottom from near Cape Hatteras to the Straits of Gibralter. One is looking northwards with the sea surface at the top. Values shown are in degrees Celsius, with the shaded region being that of apparent warming from 1958 to 1981, and the clear regions those of cooling or no change. Notice that most of the warming region is found at depth, rather than right at the sea surface. (From D. Roemmich and C. Wunsch, 1984. Nature, 307, pages 447-450).

4. Cartoon view of the circulation of the North Atlantic Ocean. Sea surface is at top. In the the polar regions, water becomes heavy owing to the extraction of heat and moisture from the ocean and is forced to sink. The water which sinks is replaced by warmer water from the south, which in turn cools and sinks in a huge conveyor belt operation. The sinking water carries with it not only atmospheric gases including CO2, but also a memory of the temperature of the air in which it was in contact.


HEAT ENTERS
CARBON DIOXIDE ENTERS
HEAT REMOVED (WARMS THE ATMOSPHERE)
WATER SINKS
EQUATOR
POLAR REGION
CARBON DIOXIDE SINKS AND IS REMOVED FROM THE ATMOSPHERE.
CO_2 INJECTED
THIS WATER IS WARM AND MOVES TOWARDS THE POLES.
COLD, NUTRIENT-RICH WATERS RETURN
CONVECTIVE REGION



5. Estimates of the sea level change with time in different parts of the world ocean. With the exception of the western North Pacific, and possibly the west coast of South America, there is clearly a global upward trend, whose significance remains debatable, but which may be the greenhouse expansion of seawater (from T. P. Barnett 1984. J. of Geophysical Research, 89, pages 7980-7988).

be dropping because in some regions of the ocean because the abyss is still cooling from long-ago climate episodes; similarly the rise we are seeing may itself be in part a slow recovery from such a cold period. We simply do not know enough to be certain.

There are trends in many other variables both within the ocean and in the atmosphere where it contacts the ocean. For example, suggestions have been made that the windfields over the ocean are changing. At the present time, we can neither prove nor disprove the connection of such trends to the atmospheric greenhouse effect, although each of us is entitled to surmises as to the proper course of action under the assumption that the changes *are* so connected.

3 What Could Happen?

Here I should make it clear that I am engaging in speculation, albeit I believe soundly based, cautious speculation.

That an atmospheric warming is occurring and will continue to occur seems to me as conclusive a scientific inference as anything in meteorology. The details of the future course of that warming are what take us into speculation. Unfortunately, what I mean by details are our very own local weather and climate in the next few decades, and the discussion gets very difficult. Where does the ocean come in?

As we have seen the greenhouse gases are entering the ocean, and everything we know suggests that much of the rising heat content of the atmosphere is also being pushed into the sea. To the extent that everything else remains fixed in the ocean/atmosphere system, these phenomena will simply continue - with the ocean ameliorating the oncoming greenhouse effect, more or less by delaying its worst consequences. The climate change would then likely be roughly consistent with that predicted by the best of the existing atmospheric models.

But the probability that the ocean circulation itself is going to remain fixed throughout this atmospheric change is extremely small. Inferences as to what those changes are likely to be and how they will affect our living conditions have, at the present time, a very large element of speculation - which goes in part as follows:

The conveyor belt depicted in figure 4 is driven by interaction between ocean and atmosphere; if one changes the nature of the interaction, by changing the atmosphere, this conveyor belt will change. What we know about the ocean suggests that the system is a very sensitive one. The best models of the atmosphere imply that the air will warm most near the poles. Such a warming would most likely result in a reduction in both the strength of the winds blowing over the oceans at high latitudes, and in the amount of heat taken from the ocean by the atmosphere. This change in turn would reduce the strength of the conveyor belt. If the water no longer becomes dense enough to sink as far or as fast as it does today, then the rate at which the ocean is removing atmospheric gases will *decrease*, and atmospheric greenhouse gases will *increase* even faster than projected. Furthermore, the rate at which the ocean takes heat *from* the atmosphere and puts it safely at depth will also decrease, and the rate of atmospheric warming could be yet faster than projected.

Should these things really happen, or be happening right now, there would be climate changes all over the world, and there is the potential for major changes in the oceanic biological cycle, changes of a potentially very damaging type.

But in telling such a story, one is going beyond what is actually scientifically demonstrable. The story I have just told is comparatively mild compared to some (e.g. the possibility of catastrophically "flipping" the ocean into an entirely different physical state), but it is not deducible on the basis either of existing oceanic measurements or theory. It is possible; it may even be likely. Beyond that one cannot at the present time go.

4 Where Do We Go From Here?

From the above discussion, it should be clear that the ocean *is* changing. However suggestive these changes may be, they remain unproven manifestations of the oncoming greenhouse effect. The problem is that we believe the ocean is constantly changing, and always has been, long before there were any human beings on the earth. We know so little about how the ocean is changing right now, and how it may have changed in the past, that we cannot perceive clearly the trends which will continue in the same direction for decades to come - because they are caused by the greenhouse effect - from those that are purely random fluctuations which will eventually reverse themselves, and have nothing whatever to do with the greenhouse.

But one is entitled to conclude that prudence dictates we should assume the effects we are seeing are greenhouse signatures. To turn the argument on its head, we cannot demonstrate either that these effects are *not* greenhouse symptoms. If they are real symptoms, and we ignore them, surely we do far more long-term harm than if precautions are taken which turn out to have been slightly premature or not strictly necessary. The worst case scenarios for the greenhouse warming, which we cannot rule out, are so fraught that we should do all in our power to slow this phenomenon so that it overtakes us, as seems inevitable, as far in the future as possible.

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I am very conscious, like many scientists testifying before Congress, that I have carefully circumscribed what I am willing to state as being true. The frustration a lawmaker must have in hearing scientists waffle is similar to my own frustration in having to take this stance. Many years ago, a number of oceanographers recognized that we were eventually going to be called upon, during occasions precisely such as this hearing, to testify about oceanic implications of the greenhouse effect.

Unfortunately, the US government has reduced its scientists to the level of supplicants - beggars for the modest level of scientific resources that would be required, so that someone else, sitting in my place 10 years from now, will not have to be equally vague and uncertain.

Statement Submitted to the

U.S. Senate Committee on Environment and Public Works

by

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National Center for Atmospheric Research
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September 14, 1988

Mr. Chairman and Senators: Thank you for the opportunity to appear before you today. In the time that you have given me I will try to (1) summarize scientific data on large-scale atmospheric changes, (2) outline some of the connections between the pollutant chemicals and their effects and how they may interact and grow larger, and (3) indicate my general support for the Global Environmental Protection Act of 1988 and a few concerns.

Brief Scientific Assessment

There are many chemicals that are being added to the atmosphere today as by-products of human activities and industry. Let me focus on those that are effective greenhouse gases, agents that deplete stratospheric ozone and pollutants that lead to regional oxidant problems and acid deposition.

The greenhouse effect is not just a theory; it has been working in nature for most of Earth's history. Without the natural greenhouse gases (carbon dioxide, water vapor, ozone, methane, and nitrous oxide), the Earth would be about 40°F colder than it is and it would be mostly or all frozen over. Our problem now and for the foreseeable future is that we are adding more of these gases and others that have the right properties to trap more and more heat in the Earth-atmosphere system, thus adding to the natural greenhouse effect and causing a variety of climate changes, not just heating.

A group of scientists (including Professor Rowland and me) critically reviewed available data in 1986, and our results were presented to you in 1987 in a brief report from the National Academy of Sciences/National Research Council; with your permission I append a copy of that report, Current Issues in Atmospheric Change, to my statement. The greenhouse gases of concern (carbon dioxide, methane, chlorofluorocarbon-11, chlorofluorocarbon-12, and nitrous oxide) have continued to increase at about the same rates as are stated on p. 4 of that report. The situation is less definite but likely similar for tropospheric ozone. Also, there is more evidence now that the present amounts of these gases are unprecedented. Some beautiful scientific measurements of the gases in old ice cores have proven that at least in the last 160,000 years there has never been as much carbon dioxide or methane in Earth's atmosphere as there is now, and this is certainly the same case for the chlorofluorocarbons and almost certainly for nitrous oxide and tropospheric ozone (the most effective ozone from a greenhouse point of view). So we are definitely pushing the Earth into uncharted territory, into a new higher energy regime whose climate will probably be different from any experienced by humans. And we are no longer free to speculate (with more naive hope than fact) that maybe past eras did have as much or more greenhouse effect from these chemicals as where we are headed.

As to climate change itself, I believe that the list of anticipated climatic effects, which we ranked in order of our confidence that they would occur, has not changed much. Global temperature records and sea-level data are being examined now very critically. Recent examinations agree that the world is warming, but the rates of temperature change that are being extracted from the data are different from scientist to scientist--the amounts of warming are sensitive to how the data are examined. But no magical ideas have materialized to allay our concerns over the coming greenhouse effect.

There have been major changes in scientists' views of stratospheric ozone depletion. In the "Current Issues . . ." report, we were somewhat skeptical that ozone depletion was actually being observed worldwide. Now after the comprehensive ozone trends assessment (led by NASA, the World Meteorological Organization, and NOAA), the evidence for depletion is compelling. There is now very strong evidence and widespread agreement that the cause of the antarctic ozone hole is manmade CFCs. The phenomenon is complex, but it would not occur without the CFCs. At the time of the "Current Issues . . ." report we did not have enough evidence to say this (and we did not). The Montreal Protocol negotiations show that other nations have also seen enough evidence to regulate CFCs and enough indications of problems from halon chemicals to act now.

Some Connections and the Potential for Surprises

A lot of our scientific research and our national policies on atmospheric and climate change have focused on one question or issue at a time. This is understandable and often necessary because of the need to delve into things deeply. But there are also interconnections that need to be explored. For example, there are some potential consequences of a climatic warming that can lead to increased warming (positive feedback). In the case of atmospheric methane, it is likely that even more methane will be released to the atmosphere from natural wetland areas and high latitude tundras as temperature increases, and it is possible that hydrate formations that contain a great deal of methane will break apart as temperature increases (shallow coastal-zone formations are perhaps most vulnerable). As summer maximum temperatures increase, so will the demands for electricity. Electrical utility networks have to be able to respond to peak power demands; high temperature extreme events have to be met.

The highest temperatures that we have experienced to date will be more likely in the future. Thus, there could be more fuel used in producing electricity. With present technology, this will mean more nitrogen oxide and sulfur dioxide gases discharged into the atmosphere. Higher temperatures would also cause more loss of hydrocarbon vapors from many reservoirs. The NO_x and hydrocarbons will lead to more ground level ozone pollution, and some of this extra ozone will add to the greenhouse capability of tropospheric ozone. Of course, the extra need for electricity will cause more carbon dioxide and carbon monoxide to be dumped into the air, and the added SO_2 and NO_x will also add to our acid deposition problems. If this kind of a scenario runs its course, the climate and environmental changes will be made larger in all of these ways.

We are also concerned about suppressing the normal channels (gaseous OH radicals) of atmospheric chemistry that consume methane and CO. If this occurs, further methane increases can occur faster than the growing methane sources alone could cause. This latter possibliity is real, but not yet proven.

Feedbacks like these are loaded on top of a disturbed system that is already very difficult to map out and predict. This committee has heard testimony previously on the record of past climate change and how rapidly changes have occurred. Some previous glaciations, weather-pattern and ocean-current changes have been sudden. Considering our present limited ability to predict exact changes and their timing and the impacts on human socioeconomic systems, health and ecological impacts, it is very risky to try to calculate the costs of such poorly defined impacts and to judge various preventive actions against those estimated costs.

Some Strategy

As you are well aware, we are looking at a future where there could be very high costs and serious impacts of climate change, ozone-layer depletion and near surface pollution--in human, economic and environmental terms. I support a multi-pronged strategy to attack this situation. It seems sensible to me to do these things: (1) intensify scientific research, (2) get started on easier control measures, (3) identify adaptive practices and get started on some of them.

As to research, this Committee is aware of our limited ability to predict all the environmental consequences of most pollutants and the consequences and their timing. We must improve, and we can do so with more commitment to basic and applied environmental research. We must map out the behavior of Earth's environmental system, its limits, its resiliency, and its patterns. As examples of areas of focus, I would mention the need to predict climatic effects on regional scales (not just global) and the temporal changes of the next decades to a century. Also, we must learn more about the chemistry of the disturbed atmosphere and of oceanic productivity and circulation. Social science research is sorely needed also to define impacts better and to help to devise adaptive strategies.

There are control measures that we really ought to start on. Some of the easier ones on which many people and interests can agree are those for which there are two or more separate reasons for action. Energy conservation is a prime example--we could decrease the U.S. trade-balance problem, improve our national and industrial efficiency, decrease our strategic dependence on overseas fuel supplies, and decrease our carbon dioxide and methane greenhouse gas pollution and lessen our regional air pollution problems. Renewable energy sources are also attractive in more than one respect. Another such example is the further more stringent control of CFCs so as to limit their future greenhouse effects and their damage to the ozone layer.

Another reason to take some actions now is that the United States will be stronger and more respected internationally by reclaiming the high ground, the highest ethical position toward global pollution. As the more difficult control measures are contemplated and the need for adaptive practices becomes apparent, the United States will benefit by having the respect of others.

The hot, dry spells of the last two summers have caused all of us to think more about effects that we might have to deal with, such as those that other witnesses are describing today. If, for example, our agricultural practices have to change and if more dependence on nuclear energy is needed (due to more energy usage and more population), let us get started now to conceive of safe and productive ways to do these things. Strength and respect will flow to the United States as a protector of the environment and a substantial market will develop in other countries for agricultural knowledge and the technologies of energy conservation and generation and for chemical production and practices.

Thus I support the goals and objectives and general strategy of S-2666, and I hope that the United States will also commit to a greatly intensified effort in relevant physical, biological, and social research.

STATEMENT OF
JAMES C. OVERBAY, DEPUTY CHIEF
FOREST SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE

Before the Joint Subcommittees on Environmental Protection and
Hazardous Wastes and Toxic Substances
Committee on Environment and Public Works
United States Senate

Concerning the Effects of Global Warming

September 14, 1988

MR. CHAIRMAN AND MEMBERS OF THE COMMITTEE:

Thank you for the opportunity to participate in this hearing on the effects of global warming. We share your concern about the effects of the prolonged drought on the National Forest System.

I would like to address four main areas: (1) the present drought and how it affects fire danger in the National Forests; (2) a summary of the last two fire seasons; (3) the effects of the drought and related fires on other National Forest System programs; and (4) Forest Service research on fire and atmospheric effects.

DROUGHT CONDITIONS

Prolonged hot, dry weather conditions have resulted in critically dry fuels, including dying and dead standing trees and an accumulation of woody slash on the forest floor. While forested lands throughout the United States are affected, conditions are most critical in the West. This is the third or fourth consecutive year of drought in several parts of the country. However, the drought is more widespread and severe this year than in previous years. Almost every one of our 156 National Forests is experiencing some type of problem related to the drought conditions.

The Forest Service uses several indices of long-term drought to help us estimate conditions for the next 30 days. The Palmer Drought Index, which is published monthly, indicates in the September 10 report that severe to extreme drought conditions will continue during the next month in California, the Northwest, Idaho, Montana, the Northern Great Plains, the Lake States, and the Southeast. The index shows some form of drought affecting 80 percent of the climatic divisions within the U.S.; and 36 percent of the U.S. falls within the severe to extreme range.

Because of the extreme drought, the moisture content of live trees is at dangerously low levels in many western States. The moisture content of large dead trees in some areas is lower than that found in commercial kiln-dried lumber. A significant amount of precipitation is critically needed to provide relief from the drought and to increase moisture levels in drought-stressed trees. If it were to begin raining now, it would take 5 to 6 months before these large logs would become saturated with water. Unfortunately, however, the long-range weather forecast for the next 30 days does not predict any significant relief for the West. Management of high risk forest fuels remains a key concern.

Although the drought period we have been experiencing during the past few years is severe, it is not without precedent. There have been a number of severe drought periods recorded in the 1800s and early part of this century. Most of these droughts have been associated with catastrophic wildfire events.

1987 FIRE SEASON

The most dramatic effect of the drought has been the intense fire seasons during the last four years. The average number of National Forest acres that burned annually during the period 1978 through 1984 is 130,000. In 1985, over 560,000 acres burned; in 1986, 353,000 acres burned; in 1987, 1.2 million acres burned; and to date in 1988, over 400,000 acres of National Forest lands have burned.

During the 1987 season, over 63,000 fires burned a total of 4.4 million acres, of which nearly 1.2 million acres were on National Forest System lands. The greatest impact occurred in Northern California and Southern Oregon, where 2000 wildfires were started during 4 days of intense dry lightning storms. These 2000 fires alone consumed 837,000 acres of public and private lands and resulted in nearly $650 million in damage to public and private property.

The total damage to National Forest System resources exceeded $630 million.

1988 FIRE SEASON

The 1987 fire season was considered the most damaging to National Forest System lands since 1919. However, present wildfire activity is greater than at this time a year ago. So far in 1988, nearly 69,000 fires have burned a total of over 4 million acres in the United States, including 2 million acres in

Alaska. As of September 13, thirty-two major fires burning on approximately 1.9 million acres continue out of control in eight western states. Over 1.3 million acres have burned in the Greater Yellowstone Area, which includes Yellowstone National Park and surrounding National Forests, with fire suppression costs near $90 million.

The preliminary cost estimate for fire suppression on the National Forests in 1988 is now in excess of $200 million, as compared to a total of $260 million for the 1987 fires. Total wildfire suppression cost for the year is expected to exceed $300 million.

Preliminary resource losses from burned National Forest System lands are estimated at more than $30 million. This does not include damage estimates for National Park Service, State, or private resources and property.

OTHER DROUGHT EFFECTS

There are long-term environmental effects associated with these fires. For example, burned areas have increased risk of soil erosion, loss of protective vegetative cover, and increased flood risks. Eroded soil and accumulated ash threaten water quality. Channel erosion damages irrigation and municipal water supplies. Noxious weeds are spread by suppression disturbance. And wildlife, fish, and livestock are displaced. The effects of smoke on air and atmospheric conditions are also a concern.

The drought conditions and extreme heat are also taking their toll on reforestation and rehabilitation efforts. Trees and grasses planted during the past two years are being killed or severely stressed. Widespread seedling mortality of first-year plantings is occurring. Losses in some areas of the Southeast and upper Midwest may exceed 30 percent. These losses could reverse the recent upward trend in acres of reforested private, non-industrial lands.

Drought-stressed trees are more susceptible to attack by insects. The potential increase in tree mortality due to bark beetles is estimated to be about 5.7 billion board feet. Pine beetle activity is increasing rapidly in Mississippi, Georgia, Alabama, California, and the Intermountain region of the West.

Domestic livestock and wildlife are competing for limited forage, particularly in the riparian areas. In many western areas, domestic livestock have been taken off of the summer range earlier than usual to protect habitat for threatened and endangered species. Drought-stressed grasses are using their root reserves to survive this year's drought. This will reduce next year's livestock forage production and grazing capacity on National Forest System lands.

Stream flows and impoundment levels continue to fall in many affected areas, adversely impacting the recreation, fishery, wildlife, and watershed resources. Low stream and lake levels diminish nesting areas for waterfowl and deplete nesting and brooding habitat for shore birds. Trout habitat losses will continue as stream flows decrease. Community water supplies may be inadequate to meet domestic and fire protection needs.

FOREST SERVICE RESEARCH EFFORTS

Research continues to provide the foundation of modern fire suppression through such diverse means as increasingly accurate computer-based fire behavior prediction systems and improved chemical retardants and application techniques. Presuppression research seeks ways both to reduce wildfire occurrence and better prepare to suppress those fires that do occur, through research on fire prevention, hazard reduction, training, and sound planning techniques. Development of long-range weather forecast interpretation capabilities will enable forces to be effectively mobilized in anticipation of fire requirements rather than in response to ongoing emergencies.

While we do not believe the greenhouse effect is necessarily the explanation of the current drought, the impacts of the current drought period on forest fires and reforestation are illustrative of the serious issues that need to be addressed. Effects of climate change on future fire suppression requirements will be large. Major changes in the structure and composition of our forests are expected to accompany major shifts in regional and seasonal precipitation patterns. These are the fuels of future forest fires.

We can also expect changes in the frequency and severity of fires. If fire frequency and severity increase in the future, then our current models of fire behavior will be inadequate.

We have developed a priority research program, Forest Atmosphere Interactions, which addresses forest productivity and health in a changing atmospheric environment. This program will build upon research efforts on chemical changes in the atmosphere that were initiated in the 1960s. This research encompasses the entire ecosystem when examining the interactions between forests and the atmosphere.

SUMMARY

The drought, which began in 1984 and continues to this day, is having a serious effect on National Forest System resources. The most dramatic effect has been the increased severity of wildfire. Less dramatic, but equally important, are the long-term effects of drought and fires on natural resources. Insect epidemics, soil losses, flood risks, forest and rangeland vegetation losses, and changes in water and air quality will have lasting effects on National Forest resources. Research by the Forest Service and others should help us reduce these impacts over time.

With the current weather prediction of continued dry weather, this year's fire season may well continue the trend of increased numbers of fires. Without significant relief, the effect of four years of drought could result in an even worse fire season in 1989.

Mr. Chairman, this concludes my statement. I would be happy to answer questions from you or other Members of the Subcommittees.

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Statement by John A. Schnittker
President Schnittker Associates
Before the Senate SubCommittees on
Hazardous Wastes and Toxic Substances and
Environmental Protection
September 14, 1988

Global Climate Change and U.S. World Food Supplies

Had this hearing been held a year ago, I might have said that large grain surpluses shield us pretty well from adverse near-term effects of global weather and climatic changes. Now, a dramatic drought has preempted those surpluses, which will be used during the next 10-12 months to fill the gap created by the drought. Reminded by the drought of our vulnerability to weather and climate, Congress and the scientific community are making a new start, to try to learn the nature and scope of adverse climatic change, in order to prepare for its effects and to identify and influence its causes.

My statement is directed to the question of preparing for the near term effects of both adverse weather for food production (which may arise partly from climatic change), and the possible long-term effects of climatic change.

> (1) It would be helpful to food and agriculture planners in government and the private sector to be better able to judge whether or not global climate change or resource exhaustion threaten the volume and stability of world food crop production. I do not know of compelling evidence that this is the case, but I am listening. Congress should increase our resources of both the National Weather Service and the relevant scientific institutions to add to the knowledge on these questions. Those resources should be used in a climate of official interest and oversight, to insure that the work is timely, relevant, and comprehensive.

(2) Congress and the new Administration should take bold steps early in 1989, to insure that U.S. reserves of grain and oilseeds are rebuilt to levels thought to be necessary for a comfortable degree of stabilization, based on the weather and climate risks ahead. Studies, regulations, and judgments about what reserve quantities are sensible, and how they should be managed, are obsolescent; few people have seriously addressed these questions since about 1975. Grain and soybean stocks will be a little below what I believe to be appropriate reserve levels by mid-1989, but others may disagree. New and urgent studies of grain reserve policies, with public, business, and government participation should be authorized, to be completed before cropping decisions are made for 1990. These studies would coincide also with consideration of revised agricultural and export policies by Congress in 1989 or 1990.

(3) The U.S. should take the lead now in placing global climatic change, possible impacts on world food supplies, and the role of grain reserves on the international agenda (U.N.; FAO; International Wheat Council). Talks addressing an international agreement on the creation and management of national grain reserves bogged down about 1976, after grain shortages and high prices were followed by good harvests. These talks should start again with U.S. leadership and support.

These are modest proposals, with very limited budgetary impact but important policy implications. If the weight of scientific evidence suggests during the next few months that climatic change almost surely threatens our food supply in predictable ways, the suggested actions would become more urgent.

CONGRESSIONAL TESTIMONY
DR. R. I. BRUCK
SEPTEMBER 14, 1988

- FOREST DECLINE IN EASTERN NORTH AMERICA -
- THE AIR POLLUTION FACTOR -

A STATEMENT PREPARED FOR PRESENTATION TO THE
UNITED STATES SENATE - COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
IN SUPPORT OF S-2666

SEPTEMBER 14, 1988

BY

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THE CONGRESSIONAL RECORD OF
THE UNITED STATES OF AMERICA 100 (2) : (000,000)

EXECUTIVE SUMMARY

MR. CHAIRMAN AND MEMBERS OF THE COMMITTEE, I APPRECIATE THE OPPORTUNITY TO APPEAR BEFORE YOU TODAY TO TESTIFY ON BEHALF OF S-2666 BEFORE THE SENATE. THIS BILL SIGNIFICANTLY MOVES TOWARDS THE REDUCTION OF MANMADE POLLUTANTS IN OUR ATMOSPHERE. MY NAME IS DR. ROBERT I. BRUCK AND I SERVE ON THE FACULTY OF BOTH PLANT PATHOLOGY AND FORESTRY AT NORTH CAROLINA STATE UNIVERSITY IN RALEIGH. I WOULD LIKE TO BRIEFLY SHARE WITH YOU 6-YEARS OF EXPERIENCE CONDUCTING RESEARCH ON THE EFFECTS OF ATMOSPHERIC DEPOSITION ON HIGH ALTITUDE BOREAL MONTANE FOREST ECOSYSTEMS IN THE SOUTHERN APPALACHIAN MOUNTAINS. NEW EVIDENCE SUPPORTING THE PREMISE THAT UNPRECEDENTED FOREST DECLINES HAVE TAKEN PLACE THROUGHOUT CENTRAL EUROPE AND THE HIGH ALTITUDE PORTIONS OF THE EASTERN UNITED STATES HAS BEEN ACCUMULATED PRINCIPALLY OVER THE PAST TEN YEARS. SEVERAL RESEARCHERS HAVE REPORTED SIGNIFICANT DECREASES IN ANNUAL RING INCREMENT GROWTH OF SEVERAL TREE SPECIES IN REMOTE AREAS OF THE EASTERN UNITED STATES.

A SYSTEMATIC DECLINE OF RED SPRUCE HAS BEEN DOCUMENTED QUANTITATIVELY IN THE GREEN MOUNTAINS OF VERMONT AND OBSERVED IN NEW YORK, NEW HAMPSHIRE, VIRGINIA, NORTH CAROLINA, AND TENNESSEE. QUANTITATIVE VEGETATION SURVEYS CONDUCTED IN THE MID-1960'S IN 6 FORESTS IN NEW YORK, VERMONT, AND NEW HAMPSHIRE WERE REPEATED 15 TO 18 YEARS LATER. BASAL AREA REDUCTIONS IN LIVE SPRUCE AVERAGED APPROXIMATELY 45% DURING THAT INTERVAL WITH THE BASAL AREA DECREASING AN AVERAGE OF 66% FOR TREES WITH A DIAMETER OF 2 TO 10 CENTIMETERS AND SPRUCE SEEDLING DENSITY CONCOMITANTLY DECREASING BY 50%. ADDITIONAL QUANTITATIVE EVIDENCE OF SPRUCE DIEBACK AND DECLINE HAVE BEEN OBSERVED IN THE CATSKILLS, THE ADIRONDACKS, AND THE GREEN AND WHITE MOUNTAINS OF THE NORTHEASTERN UNITED STATES. STANDING DEAD SPRUCE TREES ACCOUNT FOR APPROXIMATELY 22% OF THE SPRUCE PRESENT WITH AN ADDITIONAL 40%

NOTE: Attachments to this statement have been retained in committee files.

OF THE SPRUCE SHOWING SYMPTOMS OF DIEBACK. MORTALITY IS CORRELATED DIRECTLY WITH ELEVATION. MORTALITY IN SPRUCE RANGES FROM 10% IN THE HARDWOOD FORESTS OF LOWER ELEVATIONS TO OVER 30% IN THE MORE HIGH ELEVATION REGIONS.

SURVEYS BEGUN IN 1983 ON MT. MITCHELL, NORTH CAROLINA, AND SIX OTHER SOUTHERN APPALACHIAN PEAKS INDICATE THAT RED SPRUCE AND TO A LESSER DEGREE, FRASER FIR, EXHIBITED MARKED GROWTH REDUCTION BEGINNING IN THE EARLY 1960'S. SURVEYS HAD ALSO INDICATED THAT VISUAL FOREST DECLINE SYMPTOMOTOLOGY WAS OCCURRING THROUGHOUT THE SOUTHERN APPALACHIAN MOUNTAINS. WEST-FACING SLOPES APPEARED TO HAVE INCREASED DECLINE AND DIEBACK INCIDENCE ALONG WITH GREATER ANNUAL RING INCREMENT SUPPRESSION, WHICH WAS OBSERVED ON AN AVERAGE OF 82% OF ALL RED SPRUCE DOMINANT AND CO-DOMINANT TREES SAMPLED. THE RAPID DETERIORATION IN THE PHYSICAL APPEARANCE OF APPALACHIAN SPRUCE-FIR ECOSYSTEMS SEEMS TO BE IN PROGRESS, WHERE 42% AND 61% OF RED SPRUCE AND FRASER FIR TREES, RESPECTIVELY, ARE NOW DEAD IN OUR 22 PERMANENT PLOTS.

AFTER MORE THAN A QUARTER CENTURY OF RESEARCH, MANY FOREST DECLINES ARE STILL POORLY UNDERSTOOD. THEY ARE COMMONLY THE RESULT OF MULTIPLE PRIMARY AND SECONDARY STRESS AGENTS THAT EVENTUALLY CAUSE THE DETERIORATION AND DEATH OF INDIVIDUAL TREES AND ON RARE OCCASIONS, ENTIRE ECOSYSTEMS. ENVIRONMENTAL STRESSES MAY INCLUDE MAJOR CLIMATIC SHIFTS, SEVERE DROUGHTS, OR ABNORMALLY COLD OR WARM TEMPERATURES. BECAUSE OF THE POTENTIAL MULTIPLICITY OF CAUSES, FOREST DECLINES ARE OFTEN TERMED FOREST DECLINE SYNDROMES. FOREST DECLINE SYNDROMES MAY INCLUDE PREDISPOSING FACTORS; THAT INCLUDE CLIMATE, SITE QUALITY, GENETICS, AND AGE. INCITING FACTORS WHICH ARE SHORT IN DURATION AND MAY BE PHYSICAL AND/OR BIOLOGICAL IN NATURE SUCH AS INSECT DEFOLIATORS, FROSTS, DROUGHT, OR AIR POLLULTION AND FINALLY CONTRIBUTING FACTORS SUCH AS BARK BEETLES, CANKER FUNGI, ROOT AND SAP ROT FUNGI WHICH WEAKEN THE HOST AND ACCELERATE THE DECLINE SPIRAL. BECAUSE OF

THE COMPLEX RELATIONSHIPS BETWEEN BIOTIC AND ABIOTIC FACTORS, THE EXACT CAUSES OF VERY FEW DECLINE SYNDROMES HAVE BEEN SATISFACTORILY DEMONSTRATED. SEVERAL HYPOTHESES RELATING TO AIR POLLUTION HAVE EMERGED IN THE EASTERN UNITED STATES AND CENTRAL EUROPE TO EXPLAIN ONE PORTION OR MORE OF RECENT FOREST DECLINE SYNDROMES. THESE INCLUDE: 1) PHOTOCHEMICAL OXIDANTS E.G., OZONE CAUSING DIRECT ANATOMICAL AND/OR PHYSIOLOGICAL PERTURBATION TO TREE FOLIAGE; 2) HYDROGEN ION DEPOSITION LEADING TO CATION LEACHING AND DEPLETION OF THE SOIL NUTRIENTS; 3) EXCESS NITROGEN DEPOSITION RESULTING IN SUPPRESSION OF BENEFICIAL SOIL RELATIONSHIPS; 4) SOIL ACIDIFICATION AND ALUMINUM MOBILIZATION IN THE SOIL LEADING TO ROOT TOXICITY; 5) SOIL ACIDIFICATION AND METAL MOBILIZATION IN SOILS LEADING TO TOXICITY OF ROOTS AND MICROORGANISMS; 6) INCREASED SUSCEPTIBILITY OF TREES TO PEST AND PATHOGENS FROM ATMOSPHERIC DEPOSITION; 7) ALTERED REPRODUCTIVE AND DEGENERATIVE PROCESSES FROM THE DEPOSITION OF NITROGEN AND SULFUR COMPOUNDS; 8) SULFUR AND/OR NITROGEN OXIDES ALONE OR IN COMBINATION WITH OXIDANTS LEADING TO NUTRIENT STRESSES; 9) ALTERED PHOTOSYNTHESIS, RESPIRATION, TRANSLOCATION, AND CARBON ALLOCATION PROCESSES FROM EXPOSURE TO SULFUR AND NITROGEN OXIDES LEADING TO WATER AND/OR NUTRIENT STRESSES.

IN RECENT DECADES, EMISSIONS OF ACID DEPOSITION AND PHOTOCHEMICAL OXIDANT PRECURSORS; E.G., SO_x AND NO_x HAVE INCREASED THE EXPOSURE OF EXTENSIVE FOREST AREAS IN BOTH CENTRAL EUROPE AND EASTERN NORTH AMERICA TO THESE SUBSTANCES. REPORTS OF DECREASED GROWTH AND INCREASED MORTALITY IN HIGH ELEVATION FOREST AREAS RECEIVING HIGH RATES OF ATMOSPHERIC DEPOSITION HAVE INCREASED SCIENTIFIC EFFORTS TO QUANTIFY CHANGES IN FOREST PRODUCTIVITY AND TO IDENTIFY THE CAUSES. THE POTENTIAL SYNERGISTIC NATURE OF COMBINED POLLUTANT EXPOSURE AND THE RANGE OF DIRECT AND INDIRECT EFFECTS MAKE QUANTIFICATION OF THE OBSERVED EFFECTS PARTICULARLY CHALLENGING. THE

COMPLEXITY OF FOREST GROWTH PROCESSES AND THE SENSITIVITY OF FOREST TREES TO NATURAL ENVIRONMENTAL STRESSES ADD TO THE DIFFICULTIES OF QUANTIFYING THE EFFECTS OF POLLUTANTS ON FORESTS.

I HAVE SUBMITTED TO YOU WRITTEN TESTIMONY ADDRESSING THE QUANTITATIVE MEASUREMENTS OF ATMOSPHERIC DEPOSITION AND THE NUMEROUS IN SITU EFFECTS OBSERVED IN OUR STUDIES ON MT. MITCHELL. THROUGH THE RESEARCH OF THE EPA MOUNTAIN CLOUD CHEMISTRY PROGRAM WE HAVE LEARNED THAT THE DEPOSITION OF STRONG ACIDS VIA CLOUD INTERCEPTION BY TREES COMBINED WITH PROLONGED PERIODS OF HIGH OZONE EXPOSURE IN AND UNTO THEMSELVES FORM AN AREA OF GREAT CONCERN. THE FACT THAT HIGH ELEVATION FORESTS ARE ALSO EXPOSED TO HIGH CONCENTRATIONS OF GASEOUS AND LIQUID PHASE HYDROGEN PEROXIDE, VOLATILE ORGANIC CARBON COMPOUNDS, AND HEAVY METAL DEPOSITION CREATES A VERY COMPLEX SCENARIO THAT AMOUNTS TO A "CHEMICAL SOUP" WHICH THESE FOREST ECOSYSTEMS MUST EITHER ADAPT OR SUCCUMB TO. ALTHOUGH MANY GREENHOUSE AND LABORATORY EXPERIMENTS HAVE BEEN CONDUCTED TO ADDRESS THE POTENTIAL EFFECTS OF SINGLE AIR POLLUTANTS UNDER CONTROLLED ENVIRONMENT CONDITIONS, DETECTING RESPONSES IN MATURE FOREST TREES IS MADE EXTRAORDINARILY DIFFICULT BY SEVERAL FACTORS INCLUDING THE COMPLEXITIES OF SUCCESSION, COMPETITION, CLIMATE, AND SITE SPECIFIC FACTORS; THE POTENTIAL INTERACTIONS BETWEEN ACID DEPOSITION, GASEOUS POLLUTANTS, AND TRACE METALS; AND THE LACK OF UNAFFECTED (CONTROL) SITES.

AT THE PRESENT TIME NO EXPERIMENTALLY REPRODUCIBLE DEFINITIVE PROOF EXISTS THAT ACID DEPOSITION OR ITS PRECURSORS ARE CURRENTLY LIMITING THE GROWTH OR CONDITION OF FORESTS EITHER IN EUROPE OR THE UNITED STATES. DUE TO THE COMPLEXITIES ADDRESSED IN THE ABOVE FACTS, THE TASK OF ASSESSING THE POSSIBLE IMPACTS (CAUSE AND EFFECT) OF FOREST PRODUCTIVITY DUE TO ATMOSPHERIC DEPOSITION IS MADE DIFFICULT IF NOT IMPOSSIBLE, AND THEREFORE IS IN NEED OF SOLUTIONS THAT RELY ON EPIDEMIOLOGICAL TECHNIQUES RATHER THAN

THOSE INVOLVING THE DIRECT COMPARISONS BETWEEN IMPACTED AND UNIMPACTED SITES. THE STANDARD FOREST PATHOLOGY TENANTS OF KOCH'S POSTULATES THAT HAVE BEEN APPLIED BY MY PROFESSION FOR MORE THAN 100 YEARS PERHAPS HAVE LITTLE OR NO VALIDITY FOR ASSESSING THE IN SITU SITUATIONS THAT ARE PRESENTLY OCCURRING IN HIGH ALTITUDE EASTERN NORTH AMERICA. IT IS THE CONTENTION OF THIS SCIENTIST, THAT THE SCIENTIFIC AND POLICY MAKING COMMUNITIES WILL HAVE TO FIND COMMON GROUND IN DEALING WITH "IMPERFECT" KNOWLEDGE FOR THE PURPOSE OF MAKING IMPORTANT ASSESSMENTS AS TO WHETHER OR NOT MITIGATION AND CONTROL SHOULD BE IMPLEMENTED IN REDUCING ANTHROPOGENIC POLLUTANT DEPOSITION TO SPRUCE-FIR ECOSYSTEMS. ALTHOUGH THE RESEARCH INFORMATION THAT IS PROCURED BY SCIENTISTS MUST CONTINUE TO BE FUNDED, USING RESEARCH AS AN EXCUSE TO FORSTALL CREATIVE AND FRUITFUL DIALOGUE LEADING TO SOUND MITIGATION STRATEGIES IS FOOLHARDY, AT BEST, AND DANGEROUS TO THE FUTURE OF OUR TERRESTRIAL ECOSYSTEMS, AT WORST. THE DEPOSITION OF ATMOSPHERIC POLLUTANTS TO OUR EASTERN SPRUCE FIR ECOSYSTEMS OFTEN OCCURS AT ACUTE LEVELS. THE CHRONIC DEPOSITION OF MANMADE AIR POLLUTANTS ON THESE FRAGILE AND UNIQUE ECOSYSTEMS PERHAPS POINTS TO THE SPRUCE-FIR FORESTS AS AN INDICATOR OF POTENTIALLY MORE SERIOUS AND WIDESPREAD DECLINE PHENOMENA IN THE FUTURE. ONE OF MY DISTINGUISHED COLLEAGUES FROM THE UNIVERSITY OF UPSALA, SWEDEN, DR. FOLKE ANDERSEN, WHEN ASKED THE QUESTION, "WHAT DOES THE DEPOSITION OF ALL THESE AIR POLLUTANTS DO TO YOUR FORESTS?" SAID, "I CANNOT TELL YOU DEFINITIVELY WHAT THESE AIR POLLUTANTS DO, HOWEVER, I WILL TELL YOU THAT COMMON SENSE LEADS ME TO THE BELIEF THAT THEY MUST BE DOING SOMETHING." I BELIEVE THAT THIS STATEMENT VERY CLOSELY SUMS UP MY IMPRESSIONS AS A RESEARCH SCIENTIST OF THE WORK THAT HAS GONE ON IN OUR BOREAL MONTANE ECOSYSTEMS. CONTINUED RESEARCH WILL YIELD NEW IDEAS THAT MAY LEAD TO EPIDEMIOLOGICALLY SIGNIFICANT VARIABLES VALUABLE IN ELUCIDATING

THE FOREST DECLINE SYNDROME, HOWEVER, NO SCIENTIST CAN EITHER GUARANTEE THE QUALITY OR QUANTITY OF THEIR RESULTS WITH RESPECT TO ULTIMATELY PROTECTING THE ENVIRONMENT. IT IS MY BELIEF THAT IN OUR SOCIETY, BEING AS WISE AND FARSIGHTED AS WE WOULD LIKE TO BELIEVE WE ARE, IF WE ARE TO ERR WE NEED TO ERR ON THE SIDE OF PRESERVING AND PROTECTING OUR NATURAL RESOURCE BASE. DR. HERB BORMANN OF YALE UNIVERSITY IN A PAPER PUBLISHED IN BIOSCIENCE IN 1986, STATED THAT "95% OF A FOREST DECLINE SYNDROME IS NON-SYMPTOMATIC". THIS MEANS THAT A TREE MAY APPEAR TO BE TOTALLY NORMAL FOR 95% OF ITS DISEASE PROCESS AND ONLY DURING THE FINAL STAGES OF ITS LIFE WILL APPEAR TO BE SICK AND WOULD EVENTUALLY DEFOLIATE AND DIE. WE ARE THEN FACED WITH THE DILEMMA OF HAVING TO AMELIORATE THE INSULTING AGENTS IN OUR ENVIRONMENT MANY YEARS BEFORE WE EVEN HAVE DEFINITIVE PROOF AS TO CAUSE AND EFFECT ETIOLOGY, IS THERE A CHOICE?

IN CLOSING I WOULD HOPE THAT THE VARIOUS SECTORS, STATE, FEDERAL AND PRIVATE OF OUR SOCIETY WILL COME TOGETHER IN AN UNDERSTANDING THAT THE PROTECTION OF OUR ENVIRONMENT IS MORE THAN JUST AN ECONOMIC OR POLITICAL ISSUE BUT RATHER IS AN ETHICAL AND MORAL ISSUE THAT NEEDS TO BE ADDRESSED IN AN OBJECTIVE AND SCHOLARLY WAY TO PRESERVE THIS PLANET IN AT LEAST AS GOOD A CONDITION AS WE INHERITED IT. THANK YOU, MR CHAIRMAN, AND THAT COMPLETES MY ORAL TESTIMONY.

CLIMATIC WARMING AND MAMMALIAN EVOLUTION/EXTINCTIONS

STATEMENT OF:

Dewey M. McLean
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Blacksburg, VA 24061

PRESENTED TO:

United States Senate
Subcommittee on Hazardous Wastes and Toxic Substances
and the
Subcommittee on Environmental Protection
of the
Committee on Environment and Public Works

September 14, 1988

INTRODUCTION

For the past decade, I have pioneered the study of greenhouse conditions and climatic warming in global extinction events: (1) the Cretaceous-Tertiary extinctions of 65 million years ago when the dinosaurs became extinct (McLean, 1988), and (2) the Pleistocene-Holocene extinctions of about 10,000-12,000 years ago when most of Earth's large mammals suddenly died off (McLean, 1986; Attachment A).* Carbon dioxide-induced greenhouse conditions were a factor in each event. I will concentrate on the mammalian extinctions in evaluating effects of a modern greenhouse upon mammalian faunas.

A major thrust of my work has been to develop linkage between climate and mammalian bioevolution, in which I have isolated a direct coupling between high environmental air temperature and reduced mammalian reproductive capability. High environmental temperatures can reduce population numbers, thus influencing evolution. Via integration of ice age climatology, mammalian reproductive physiology, and the paleontological record, I believe that sufficient understanding of climate-evolution linkage has emerged to predict how a modern greenhouse might affect mammalian faunas.

A CLIMATIC OVERVIEW

During the past two million years, Earth has experienced numerous ice ages. During each ice age (glacial cycle), great ice sheets have developed over land areas in the high-middle latitudes of the northern hemisphere. Each glacial cycle (Fig. 1) lasts about 100,000 years, and is terminated by rapid climatic warming. The periods of warmth at the end of glacial cycles, termed interglacials, last about 10,000 years; interglacial warming immediately follows the coldest stage of the glacial interval. Ice age climatology is driven by variations in Earth's orbit, and by varying amounts of CO_2 in the atmosphere.

Examination of Fig. 1 shows that, in an evolutionary sense over the past several million years, mammals have spent most of their time (100,000 year intervals of a glacial cycle) in a relatively cool world, and short periods (10,000 year intervals of an interglacial) in a warm world. By examining the temperature curve of Fig. 1, we find that we live in a relatively hot world. Maximum warming of this interglacial was about 6,000 years ago when the climate was 0.5-1.0°C (0.9-1.8°F) warmer than today.

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*Retained in committee files.

If humans were not present on Earth, the climate would likely cool into a new ice age as it has done many times in the past; however, our burning of the fossil fuels is increasing the content of greenhouse gases in the atmosphere such that some degree of greenhouse warming is possible prior to any significant cooling.

In assessing the impact of climatic warming on modern mammalian faunas, we should consider the following points: (1) today, we live in an already relatively hot world, (2) many modern mammalian species already experience considerable environmental heat-induced reproductivity problems, (3) because of polar amplification of warming during a greenhouse, mammals of the middle and high latitudes will experience a greater temperature increase to have to adapt to than will mammals at low latitudes, (4) in the middle latitudes where we live, maximum conception rates are in the cool winter months; during a greenhouse, the maximum warming will occur in the winter months, interfering with the optimum time of breeding, and (5) a too-rapid warming event could outpace the capacity of mammalian faunas to adapt to the new heat load.

A rapid transgression of sub-tropical climatic warmth over cool-adapted middle latitude mammalian faunas will result in lowered conception rates, the degree of damage being a function of the rate, and magnitude, of temperature change. The next section addresses the sensitivity of modern middle latitude mammals to existing levels of environmental temperature.

THE ENVIRONMENTAL TEMPERATURE-REPRODUCTIVE FERTILITY LINKAGE

Seasonal decreases in fertility associated with heat stress are due primarily to female mammals. The mechanism by which high environmental temperatures trigger reproductive dysfunction in female mammals (developed in Attachment A) is outlined as follows.

High environmental temperatures induce hyperthermia in female mammals. As a defense against heating, blood flow is shunted to peripheral tissues in order to dissipate heat to the environment; this reduces the flow of blood to the uterus. Uterine blood flow is a developing embryo's source of oxygen, water, nutrients, and hormones, and transports metabolic heat away from the embryo. Reduction of uterine blood flow can damage, or kill, a developing embryo.

A developing embryo must be maintained at a nearly constant temperature; a 1.0-1.5°C (1.8-2.7°F) temperature rise above optimum will damage, or kill, most embryos. Environmental temperatures of about 30°C (85°F), and higher, cause the core temperatures of pregnant female mammals to begin to rise. High humidity lowers the temperature at which core temperatures begin to increase. Core temperatures of lactating cows may begin to rise at about 21°C (70°F).

High temperatures act directly upon the embryo with the greatest effect immediately following fertilization, during the initial stages of cell division; heat at that time may alter rates of metabolism with the embryo, perhaps interfering with RNA synthesis.

Heat can also induce dwarfing. Intrauterine growth retardation results from exposure of pregnant females to high temperatures during late gestation, and may result from reduced uterine blood flow.

Hyperthermia during pregnancy can also produce skeletal abnormalities, the effects dependent on the stage of pregnancy at the time of exposure.

Evidences that environmental heat reduces fertility are cited below:

Johnson (1985) notes that conception rates and fertility decrease in the summer in temperate zones, and in subtropical and tropical climates. In Arizona, the normal insemination rate of 50 percent in cool months may drop to 20 percent in the hot months. In Missouri, average herd conception rates of 50 percent in winter drop to 0-20 percent for July and August.

Thatcher (1974) notes that environmental conditions associated with subtropical areas contribute to lower reproduction and milk production. Fertility is inversely related to the maximum environmental temperature the day after insemination and to uterine temperature both at insemination and the day after insemination. In lactating cattle, environmental temperatures above 21°C (70°F) cause deep body temperatures to rise sufficiently to reduce conception rates. Among Florida cattle, as maximum environmental temperatures increased from 21.1 to 35°C (70-95°F), the conception rate declined from 40 to 31 percent. Average maximum temperatures for May through September ranging from 30.7-32.7°C (87-90°F) exert a thermal stress associated with decreased fertility.

Gwazdauskas et al. (1981) note for Virginia cattle that the optimum environmental temperature for conception ranges between 10°C and 23°C (50-73°F). The decline in fertility when temperature the day after insemination exceeded 23°C is typical of that for southern climates and may be from detrimental effects of heating embryos during early cleavage stages.

Dunlop and Vincent (1971) exposed a group of heifers, after breeding, to 32.2°C (90°F), and another group, after breeding, to a constant 21.1°C (70°F).

None in the first group maintained pregnancy, whereas about half of the low temperature group did so.

Ulberg and Burfening (1967) reported that pregnancy rates declined from 61 to 45 percent as the rectal temperature (which gives an estimate of core temperature) increased 1.0°C (1.8°F).

Among hogs, temperatures of 18 to 21°C (64-70°F) are optimal in terms of productive performance. For each Celsius degree above 21°C (70°F), hogs gain 35 to 60 grams less daily than at optimum. Sows mated during hot weather show markedly reduced farrowing rates, due partly to increased frequency of early embryonic death. The conception rate is also reduced.

Table 1 shows the acceptable temperature ranges of some of the more important farm animals, and provides a basis for evaluating how abrupt climatic warming of several Celsius degrees could affect mid-latitude adapted mammals. Greenhouse warming that would increase the number of days with temperatures in the 30°C (86°F), and above, range would far exceed the acceptable temperature range of important dairy animals, causing great loss in production. Problems will track the warming, and expand in scale with it.

ANIMAL	ACCEPTABLE TEMP RANGE °C	(°F)
Dairy Cattle (lactating or within 2 weeks of breeding)	4-24	(39-75)
Calves	10-26	(50-79)
Beef cattle	4-26	(39-79)
Sheep	4-24	(39-75)
Poultry:		
Growing (over 10 days old)	13-27	(55-81)
Laying hens	7-21	(45-70)

Table 1 (after Hahn, 1976). The "acceptable temperature range" is the average daily temperatures of long-term exposure causing nominal losses in production and efficiency of livestock. For high radiant heat loads, the range should be shifted downward at least 3°C.

Humans are not immune from thermal-biological principles that govern adaptation to climate zones. Fig. 2 (after Macfarlane, 1974) shows that humans are reproductively adapted to the climate zones in which they live. Human conception rates are influenced by environmental temperatures; at the latitudes of the mid-and southern United States, maximum human conception rates are highest in the cool months, and fall off during hot summer months. A ten year study of human fertility in Galveston, Texas (Lamar and Rodgers, 1943), showed that conceptions were least frequent in July and August when temperatures were highest 29°C (83-84°F), and most frequent in January when temperatures were lowest 13°C (56°F); the percentage increase from lowest to highest conception rates averaged 77 percent. Stillbirths were 134 percent higher during hot months.

Other effects of high environmental temperatures are to decrease litter size and neonatal survival, milk production, and estrus; to stunt growth after weaning; and to increase disease and parasites.

RELATIVE TROPICAL AND MID-LATITUDE WARMING DURING GREENHOUSE WARMING

Several general circulation models have estimated surface air temperature change for doubled atmospheric CO_2 concentration (from Schlesinger and Mitchell, 1985). They are the GFDL (Wetherald and Manabe, 1986), GISS (Hansen et al. (1984), and the NCAR (Washington and Meehl, 1984) models. Generally, warming is minimum in the tropics in both summer and winter seasons; tropical warming ranges from 2-4°C (3.6-7.2°F). For North America, winter warming is greater than summer; the GFDL and GISS simulations show warming of 4°C (7.2°F) in the south to 10°C (18°F) in the north. The NCAR model simulates less than 4°C (7.2°F) over most of North America.

During the climatic warming at the end of the last ice age, mammalian faunas of tropical areas were little affected by extinctions, whereas mammalian faunas of middle and high latitudes were severely affected. North America lost nearly 70 percent of the genera of large mammals.

PREDICTIONS ON EFFECTS OF CLIMATIC WARMING ON MAMMALIAN FAUNAS

Knowledge of environmental temperature and embryogenesis function/dysfunction coupling permits predictions on how significant climatic warming might affect mammalian faunas. They address:

1. Reduction in population numbers caused by widespread heat-induced embryogenesis dysfunction.
2. Large mammals will suffer greater losses than small; the relatively small surface/volume ratios of large mammals cause them to retain body heat to a greater extent than do small mammals.
3. Dwarfing. Intrauterine growth retardation which produces proportional dwarfs results from exposure to high environmental temperatures during late gestation.
4. Skeletal abnormalities. Climatic stress, or hyperthermia, during pregnancy produces fetal malformations in some species, the effects of temperature dependent upon the stage of pregnancy.
5. Reduction of the middle latitude winter breeding season because of relatively greater winter warming associated with greenhouse warming.
6. Relative severity of thermal effects upon middle to high latitude mammalian faunas. Because of the polar amplification of warming, middle and high latitudes will heat up relatively greater than tropical regions, subjecting mammalian faunas to a relatively greater heat load to have to adapt to.

PREDICTIONS TESTED AGAINST THE PLEISTOCENE-HOLOCENE MAMMALIAN EXTINCTIONS

Coeval with rapid climatic warming that terminated the last glacial cycle (Fig. 1) were the Pleistocene-Holocene global mammalian extinctions. Nearly 70 percent of North America's megafauna died out between 15,000-8,000 years ago, with most perhaps disappearing about 12,000-10,000 years ago. Grayson (1987) proposes that population numbers of many genera that became extinct toward the end of the Pleistocene may have significantly dwindled by 12,000 years ago, and that many genera yet to be dated may not have survived beyond 12,000 years ago. This antedates the often-proposed 11,000 year-ago arrival of humans in North America.

Significantly, most mammals survived the most extreme cold glacial stage of 20,000-18,000 years ago, a time of maximum glacial advance, reduction of living space and food supplies. Then, during the climatic warming that terminated the ice age, as living space was expanding, and food supplies were increasing, mammalian extinctions occurred. Those extinctions accord with the predictions of effects of high environmental temperatures on cool-adapted mammals: large mammals exceeding 44 kg (100 lbs) were most selected against, dwarfing occurred on a global scale, skeletal abnormalities occurred in some genera, and the extinctions were most severe in high and middle latitudes.

Not all glacial cycle terminations trigger extinctions; they seem to occur during terminations of the most severe cold stages (Webb, 1984). Warming during the termination 125,000 years ago apparently did not trigger extinctions. However, that cold stage was not as severe as the one at end of last ice age; evidence is that tulip trees and pines persisted through the earlier cold stage in Illinois whereas they did not do so in last glacial cycle (personal communication, Jim King).

CONCLUSIONS

In an evolutionary sense, mammals have spent most of their time in a relatively cool world, and relatively short periods in warm interglacials. Today, we live in an already warm interglacial—prior to the onset of any potential greenhouse warming. Evidence abounds that many mammalian species already experience heat-fertility problems during modern hot summers. Any significant greenhouse warming would only exacerbate fertility problems.

Mammals are generally adapted reproductively to the climate zones in which they exist. Fig. 2 indicates how human conception rates relate to climate zones. A low magnitude, gradual, greenhouse warming would present minimal adaptational problems to overcome. However, an abrupt, and severe, temperature increase would likely outpace the capacity of many species to readily adapt to it, fulfilling the above-cited predictions on the effects of climatic warming on mammals.

Middle latitude mammalian faunas may be especially affected by greenhouse warming. Because of polar amplification of greenhouse warming, middle latitude faunas would have a relatively greater heat load to adapt to than would tropical faunas. Moreover, in the middle latitudes, the cool winter months are the prime breeding season. The relatively greater wintertime than summertime warming would reduce breeding time in the middle latitudes.

Few mammalian species of the middle latitudes would likely get through a major greenhouse unscathed.

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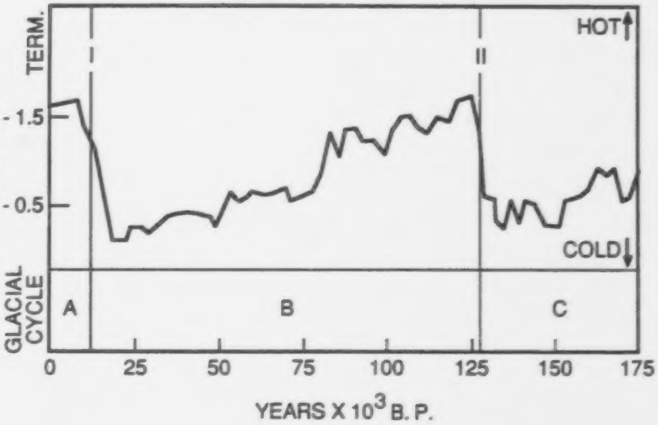

Figure 1. During the past two million years, Earth has experienced numerous ice ages, or glacial cycles. Each cycle lasts about 100,000 years, and is characterized by gradual cooling that is terminated by relatively rapid warming. The coldest stage of an ice age usually immediately precedes the abrupt warming. The period of greatest warmth at the beginning of a glacial cycle is termed an interglacial; interglacial periods last about 10,000 years. In an evolutionary sense, mammals have spent most of their time in a relatively cool climatic conditions, and but short periods in warm interglacials. Today, we live in a warm interglacial; the maximum warmth of this interglacial occurred about 6,000 years ago, when the temperature was about 0.5-1.0°C higher than today. Most mammals seem to have survived the coldest stage of the last ice age, at which time ice sheets covering large areas of the high-mid latitudes of the Northern Hemisphere would have reduced living space and food resources. About 12,000-10,000 years ago, as earth was warming up, and living space, and food supplies were expanding, mammalian extinctions, dwarfing, and skeletal abnormalities occurred. Modern mammalian faunas are the survivors of that extinction event.

HEAT ADAPTATION: HUMAN CONCEPTION

REGION	LAT.	MAXIMAL	MINIMAL	
			Summer	Winter
N. Europe N. USA Tasmania, N. Z.	40 - 60	63°F	54°F	37°F
Mediterranean Mid & S. USA Northern India Australia	23 - 39	61°F	73°F	50°F
Southern India N. Australia Singapore	2 - 22	77°F	84°F	-
Ceylon N. T. Australia	0 - 12	81°F	77°F	-

(Macfarlane, 1974)

Figure 2. Mean monthly temperatures and maxima and minima of human conception in different latitudes (after Macfarlane, 1974). The different mean monthly temperatures at which maximum and minimum rates of conception occur over the world indicate that there are different levels of human habituation to temperature. Whereas acclimatization is a complex of cellular, vascular and endocrine events, habituation is essentially a change in the central nervous response to repeated fairly strong stimuli. Tropical human populations are habituated to a temperature in the upper 20's Celsius (about 81°F) and function best in such an environment. In the middle latitude warm temperate regions of the mid and southern United States, conception is greatest at about 16°C (61°F); here, maximum conception rates occur in the cool winter months; minimal conception rates occur at temperatures similar to those that give maxima in the subtropics.

The Anthropology of Environmental Decline

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Is Our Predicament So New?

Current news on environmental problems frequently emphasizes the totally unprecedented nature of the ecological crises that beset us in this nation and the western world as a whole. We are told, for example, that the last few months constituted "the hottest summer on record" in North America. Similarly we hear that Boston harbor has never in its history been so polluted, and in European waters seal populations are now dying of an epidemic on a scale never before witnessed by man.[1] By stressing this "never before" aspect of events, it is sometimes argued that the experience of the past is largely irrelevant for policy planners. Since circumstances are so new, so the argument goes, past experience leaves us with little or no instruction in the formulation of a practical public policy for the environment.

This is not altogether true. While particular types of industrial pollution may be new and the scale of ecological devastation may be greater now than previously, recent research demonstrates that the western world is *not* confronting completely unprecedented circumstances. We need only cast our gaze over a somewhat enlarged horizon to realize that numerous civilizations before our own have confronted environmental degradation. Moreover, many regions of the non-western world are currently facing and some are coping with environmental deterioration in our own time.

Historians and archaeologists have studied examples of ecologcial collapse in past civilizations while anthropologists are examining contemporary examples of ecological degradation in non-western cultures. In our urgent concern to formulate effective environmental policy in the United States, it would be wise to keep the insights of this historical and cross-cultural research clearly in mind, lest public leaders commit our society to repeating and amplifying the tragic blunders of other cultures and past civilizations. If we continue to tie our society's infrastructure and agricultural production to a declining resource base -- as ancient civilizations did with such depressing regularity -- we too will suffer the fate of unavoidable collapse.

The Ecological Decline of Ancient Civilizations:

The record of anthropogenic ecological degradation is, unfortunately, very ancient indeed. Since at least the advent of sedentary agriculture mankind has acted as a powerful biological and geological agent in complex ecosystems, almost invariably without a corresponding awareness of its own impact upon the environment. For this reason, conscious statements by witnesses from the past or from other cultures in our own day have not adequately reflected the full scope of human involvement in ecological decline. Thus, written or oral records are not in themselves sufficient for investigating the question of human agency in ecosystems. Nevertheless, new research techniques have revealed that many catastrophes which have long been understood as "acts of God" or "natural disasters" were in fact largely generated or substantially aggravated by collective and cumulative human behavior.[2]

The repeated pattern of the rise and fall of ancient civilizations in the circum-Mediterranean region is especially revealing in this respect. Recent archaeological research indicates that there was a substantial ecological component to the emergence and collapse of agricultural complexes in ancient Mesopotamia, Phoenecia, Palestine, Egypt, Greece and Rome.[3]

These urban-based civilizations had to solve the basic problem of producing food surpluses and collecting raw materials from rural areas to sustain the non-agricultural activities of populations engaged in commerce, ritual, government and the arts. Over time the strategies that each society pursued to produce food and procure resources left their characteristic mark on the environment they inhabited. Some of these strategies proved not to be sustainable in the long run. Local populations either overtaxed the natural resource base of the region (depletion of water, soil, or forest reserves) or the repeated agricultural demands on the land exceeded its long-term carrying capacity. The general pattern was one of gradual emergence, brief efflorescence, and rapid collapse of civilizations, often taking the form in the final stages of devastating military struggles for the control of arable land or a declining resource base.

Techniques of agricultural intensification, -- terracing, crop selection, animal husbandry, irrigation, and the like -- were devised to meet repeated crises of production. Despite short-term improvements in output, however, the long-term consequences of these technologies were not foreseeable by early agricultural innovators. In subsequent decades or centuries problems of over-grazing, water-shed deforestation, soil erosion, siltation, water-logging, soil salinization and crop blight often emerged as the long-term consequences of earlier innovations, sometimes leaving whole regions permanently destroyed for agricultural use.

Written documentation concerning these phenomena frequently presents explanations in terms of military, political or religious rivalry and conflict, perhaps most obviously because the elites that wrote such literature were part of military, political or religious institutions in the societies concerned. Nevertheless, no matter how persuasive this literature is, these explanations inevitably oversimplify and distort a more fundamental understanding of the dynamic of agricultural civilizations.

Current archaeological research based upon scientific analysis of soil profiles, vegetation, and landscape evolution indicates that in the rise and fall of ancient civilizations there was at the base of nearly all sustained conflict an irreducible ecological component. Patterns of rivalry in the circum-Mediterranean could express either a momentary ecological crisis or a long-standing decline of some fundamental element of ecological capital of the agricultural systems concerned. The ecological dislocations were frequently most visible in the "peripheral" areas of the great mediterranean empires, for it was here that the imperial powers established systems of commercial agriculture and proceeded to exact levels of agricultural production that exceeded the ecological capacity of the land.[4]

The Ecology of European Expansion:

The sobering ecological lessons of the ancient world may well have been kept clearly in our collective consciousness were it not for the exceptional history of the Western world over the last five hundred years.[5] This recent experience has overshadowed -- indeed, nearly totally eclipsed -- the lessons that we should have learned from the repetitive decline and collapse of ancient agricultural civilizations. It can be argued that this recent history has been responsible for a potentially fatal, cultural blind-spot concerning the vulnerability of our current industrial system of agriculture. Because of its experiences between roughly 1450 and 1950 -- a period marked by seemingly unlimited expansion -- the Western industrial world now finds itself conceptually ill-equipped to understand and politically impotent to address the problems of ecological adjustment that currently face all societies in our modern, finite world.

Ironically, it is precisely the remarkable "ecological success" of European cultures that has led to their current ecological myopia. Recent research on the historical ecology of European expansion makes this abundantly clear. Briefly put, Europeans were able to expand with such rapid success throughout great portions of the world between 1450 and 1950 largely because their microbes, viruses, weeds, pests and plant and animal domesticates proved to be more hearty than indigenous species in competition for survival in distant lands around the world. It was the success of their "biological allies" that paved the way for Europeans to dominate much of the modern world.[6]

The comparative success of the Europeans's biological allies ultimately stemmed from the evolutionary history of microbes, plants and animals. Essentially, the antiquity of agricultural practice and urban civilization in the Old World meant that diseases, weeds, cultigens and herbivorous domestic animals had developed highly effective mechanisms for feeding or breeding simply to remain alive in the context of close competition with other species. Hence, many of these organisms were equipped with more effective defenses, better dispersal mechanisms or more aggressive behavior than the species occupying similar eco-niches in the newly discovered colonial territories.

With the help of their "biological allies" European agriculturalists quickly exploited the natural capital of vegetation and fertile soils in regions where indigenous populations were either sparcely settled agriculturalists or foraging nomads. The pattern of biological intrusion was frequently devastating for indigenous flora and fauna and often led to a substantial modifications of local biotic communities, alterations of the regional hydrology and the devastation of age-old topsoils.[7]

The net effect of colonial discovery and settlement was to transform European agricultural techniques substantially in the New World, even as the New World itself was being physically transformed. In this process, some age-old agricultural wisdom appears to have been lost. Conservation of resources simply seemed no longer necessary in the circumstances of comparative abundance. Whereas intensive techniques of resource husbandry had come to characterize the confined land-base of medieval European agriculture, the New World afforded rich new possibilities for agricultural expansion. In effect, since the discovery of the New World, predatory expansive agriculture and parasitic resource use came to characterize European civilization, leading some emergent cultures -- including our own -- to believe in a mythology of expanding "frontiers." This was an historically plausible mythic image, and for centuries the mythology of "frontier cultures" could be sustained and verified by numerous cases of parochial experience.

It is important to realize, however, that increases in agricultural output over most of this period were accounted for not so much by improvements in basic technology as they were by the overall expansion of the land surface under cultivation. While total production rose dramatically, productivity per acre and productivity per unit of energy input often declined. Nevertheless, profits from total agricultural surpluses helped to finance the emergence of urban-based industrial systems. The dynamic of industrial growth served, in turn, to sustain the mythology of "unlimited frontiers" and further transformed these formative frontier myths into a belief in perpetual economic growth. Having expanded upon the things of nature, the West came to believe that expansion was in the nature of things. Perpetual growth was considered both natural and good.

The European experience of overseas expansion and the ensuing pattern of industrialization has engendered deep-seated habits of thought and images of cultural self-perception.[8] In our day these images and mental metaphors leave the industrial world very poorly equipped to construct a viable system of stable production in our finite circumstance. In effect, we are trying to sustain a "frontier culture" in a post-frontier world. Little wonder that our environmental policy is so embarrassingly immature.

"Development" and Ecological Degradation in the Contemporary Third World:

The decline of past civilizations or the violent and explosive characteristics of colonial ecologies might well remain comfortably remote from us in our twentieth century world were in not for the disturbing parallels that such case histories seem to evoke as we consider our contemporary global circumstance. Just as in ancient times and in the age of colonial expansion it is in the "remote environments," usually quite distant from the centers of power, that the crucial indicators of environmental catastrophe first become apparent within the system as a whole. These regions are frequently characterized by weak economies and highly vulnerable ecosystems in our time just as they were in the past. Because of these attributes, the environmental circumstances in these regions constitute a kind of monitoring device in the modern world that can provide us with an early warning mechansim for the ecological stability of the global ecosystem as a whole.

If we begin to monitor this early warning system, we will recognize that the signs are not encouraging. One observer has summed up the overall situation quite succinctly:

> "...the last thirty years have been the most disastrous in the history of most, if not all, Third World countries. There has been massive deforestation, soil erosion and desertification. The incidence of floods and droughts has increased dramatically as has their destructiveness, population growth has surged, as has urbanisation, in particular the development of vast shanty-towns, in which human life has attained a degree of squalor probably unprecedented outside Hitler's concentration camps.
>
> With such developments, have come increased malnutrition and hunger; so much so, that today we are witnessing for the first time in human history, famine on a *continental scale*, with two-thirds of African countries to some degree affected."[9]

While it is most convincing to witness these trends in the field, their reality is apparent to anyone capable of a sensitive reading of available figures and reports that deal with aggregate populations or macro-level change. Several well-documented environmental and economic trends are of particular importance in this connection.[10] These include problems of deforestation, the expansion of petro-chemical agriculture, the shift in weather patterns and perhaps climate in the semi-arid areas, continued population growth and the penetration of local food markets with Western food surpluses through dumping or foreign aid.

One of the most familiar among the measured environmental trends in the Third World is the phenomena of tropical deforestation. While anthropologists have observed this on a micro-ecological basis for several decades, it is now becoming measurable from satellite monitors in space. The scope of the transformation is massive. In March 1984 the Office of Technology Assessment (OTA) reported to the United States Congress that deforestation in tropical areas was proceeding at an alarming rate: "Each year approximately 11.3 million hectares (4.57 million acres) of the Earth's remaining tropical forests - an area roughly the size of Pennsylvania - are cleared and converted to other uses," the report indicated. If current trends persist, the report makes clear that much of the earth's tropical rainforest will be gone by the turn of the century. It estimates that at current rates, "Nine tropical countries would eliminate practically all of their closed forests within the next 30 years and another 13 countries would exhaust theirs within 55 years."[11] Attempts to re-forest denuded areas have been made, but estimates are that areas that re-forestation efforts account for only about one tenth the area of areas deforested at the current time.

Those areas affected are in all of the tropical regions of the world. Nations experiencing the worst deforestation include the Ivory Coast in West Africa, where 6.5 percent of closed forests are lost each year; Nigeria in West Africa, 5 percent; Paraguay in South America, 4.7 percent; Nepal in Asia, 4.3 percent; Costa Rica in Central America, 4 percent; and Haiti in the Caribbean, 3.8 percent.[12] The OTA study joins a chorus of others that have been published recently, for efforts to publicize the fate of tropical forests have been made by scholars and researchers for several years.[13]

As scientists are informing us the tragedies involved in the loss of tropical forests are far greater than the hardships these loses impose on local peasantries or isolated ecologies. Indeed, the impact of tropical deforestation is global in scale for three main reasons. First, the tropical rain forests are perhaps the greatest remaining store of biological diversity left on the planet. Secondly, these ecosystems play a major role in the bio-geo-chemical cycling of carbon and the earth's atmospheric gases. Thirdly, and partly as a result of their role in the bio-geo-chemical cycles, the tropical rain forests appear to play an as yet unclear but nonetheless important role in the regulation of the earth's climate.

Despite the volume of already published scientific studies and others underway that warn against the dangers, the pattern of deforestation, has not been noticeably reversed by acts of policy in recent years. Third World countries involved in the process of forest loss are by now genuinely concerned about this form of ecological degradation, but they are frequently impotent to do anything more than monitor what has occurred. In 1987, for example, an environmental group known as The Mexican Ecological Movement indicated that: "The unplanned cutting of timberland in the past 30 years has caused Mexico to lose 45 percent of its forest reserves....in 1957 Mexico had 3 million acres of forest, compared with some 1.8 million acres of current wooded lands."[14] Much of this forest loss is not of the same kind that has occurred by explicit timbering of tropical forest reserves, but the resource loss to peasants is nevertheless real and dramatic.

In some cases, localized patterns of deforestation can cause national and potentially international complications. Deforestation in the Himalayan highlands has been seen to be linked over time to the pattern of flooding down river in Bangladesh. More than 25 million people are homeless now and subject to disease and famine in the coming weeks and months because of watershed deforestation in the Himalayan ranges. In addition, the process of deforestation currently proceeding in Panama seems to be affecting not only peasant welfare and local agriculture but potentially the integrity of the canal passageway itself. A report issued to the government of Panama indicated that the Canal's most pressing problem is that of deforestation. In 1952, 80 percent of the Panama Canal basin was covered with forest, while today only 20 percent remains forested. "The jungle is being deforested at the rate of 5,000 acres per year," the report indicated.

The loss of forest cover on hills and mountain sides allows soil to be washed down into the lakes and connecting waterways causing siltation. The Panamanian governmental report estimated that this kind of erosion was expected to reduce the Panama Canal's capacity by 10 percent in the year 2000. The report, coordinated by Stanley Heckadon Moreno, an environmentalist at the Planning Ministry in Panama, stressed the urgency of acting immediately to reverse current forest-loss trends. "We believe," the report authors said, "that unless corrective measures are taken immediately, the basin will be totally deforested and the useful life of the Canal will be reduced to less than 25 years."[15]

As the Panama circumstance indicates, many of the causes leading to deforestation are to be found in the desperation of landless peasant families seeking new territories for farming. UPI Reporter Elizabeth Love summarized the situation in these terms:

> A steady stream of landless peasants has been invading the land around the Canal. They earn a meager existence by raising cattle and raising crops by using slash and burn agriculture, both activities that destroy trees and native plant life that protect the soil.
>
> Some 40 underequipped forest rangers patrol the 1,280 square miles that make up the Canal watershed, but stemming the tide of migrants and persuading the farmers to move on is difficult.
>
> "(If) the government simply tells them by means of the armed forces or forest rangers _ 'You can't cut the forest,' the peasants perceive that as you saying 'You can't eat,'" said Heckadon Moreno.
>
> He said some 50,000 peasants already live in the Canal basin area and the figure is expected to grow 7 percent annually.
>
> If peasants are not offered an alternative in the way of jobs or land, "political restlessness" could further hinder Canal programs,

> Heckadon Moreno said.
> "Just the other day, 50 or 60 families created a situation in which weapons had to be drawn (to evict them). What are we going to do in five years time when we have mass amounts of people there, demanding land?" he said.[16]

While deforestation in Panama and in many African countries may be the collective result of individual actions undertaken by small household peasants, elsewhere it seems to result from explicit policy decisions for development projects proposed by corporations or national governments and supported by the international financial community. Environmental groups like the Rainforest Action Network and the Tropical Forest Action Group have directly linked the loss of forest resources to the type of development strategies pursued by nation states and financed by the World Bank.[17]

Randall Hayes, director of the Rainforest Action Network indicated at a conference in Boulder, Colorado in February 1987 that he intended to wage a campaign to arouse public opinion against the international financing of development projects that had the direct or indirect effect of destroying tropical rainforests. Pointing out that international financial backing is required to launch many of the cattle ranch and agriculture development projects that have a direct impact upon the tropical rainforest, Hayes argued that if the flow of supporting capital could be stopped, the rate of deforestation could be slowed. "It's a battle that can be won,..." he said, "It takes money to finance this destruction. If we can stop the money, we can stop the destruction."[18]

Other protests against World Bank development policies have taken more direct action. Last September members of the Tropical Forest Action Group were arrested as they demonstrated against World Bank policies by unfurling 40-foot by 20-foot banner from an 11 story building near the World Bank headquarters. The banner read simply: "World Bank Destroys Tropical Forests." It was meant to be seen by finance ministers and world economic policy officials as they met in Washington to discuss future lending policies of the World Bank. More recently, adverse publicity for the Bank's policies has focused upon the ecological devastation that Bank lending helped engender by helping to finance extensive highway construction in the Amazon basin.[19]

If changing the consciousness of international finance organizations is sufficient, there may be some room for optimism here. At the highest official levels, at least, there seems to be an emerging consensus that something must be done. Perhaps in response to increasing accusations that it has been bankrolling environmental destruction or in response to its own internal policy review, the World Bank announced intentions in May of 1987 to give environmental concerns top priority in future lending decisions. World Bank President, Barber Conable, indicated, in a speech to the World Resources Institute in Washington, that explicit efforts would be made in the future to halt the spread of deserts in Africa. "The World Bank is a force for development and will remain so," he said. "Our role in such projects, however, will include greater sensitivity to their long-term environmental effects. And we will put new emphasis both on correcting economic policy incentives that promote environmental abuse, and on stimulating the small-scale activities that can combat human and environmental deprivation."[20]

The remaining questions are simply these: is this kind of gesture too little, too late? Even with the best of intentions can large international organizations like the World Bank effectively reverse a pattern of Third World decline that has been underway for over thirty years? Is there not a fundamental contradiction between environmental conservation and "development" as it has traditionally been conceived? Environmentalists are beginning to phrase the question in just these terms: "Is development the solution or is it the problem?"[21]

The issue of tropical deforestation may prove to be a weather-vane case, indicating whether institutions can adapt quickly enough to changing circumstance in the Third World. The World Bank intends to raise its funding from $138 million to $350 by 1990 for studies to preserve tropical forests. Moreover, it recognizes the need to fund projects that promote conservation, but it may well be that projects of this kind would require flat opposition to "development" programs that have been launched and are likely to continue in the Third World. In any direct confrontation between the newly informed consciousness on the part of World Bank donors and the entrenched special interests advocating conventional forms of trade, aid and development in the Third World, it is not clear that the newly discovered environmental sensitivities of World Bank officials will prevail. Indeed, there are mounting signs that the policies of development that have caused the most rapid and irreversible forms of environmental degradation are likely to endure. In fact, these policies are likely to be applied in an accelerated manner in the coming years, despite the best intentions of the World Bank's officials.

The Dynamic of Environmental Degradation: The Underdevelopment Spiral

The reason for this can be located in what might be called most generally: "the underdevelopment spiral." This is a syndrome of closely related social, economic and ecological phenomena which when taken together work to engender a self-perpetuating cycle of environmental decline. As these phenomena interact they work to re-inforce one another in a synergetic manner, accelerating a spiral of decline and making it increasingly difficult for any one party to intervene to arrest the process. To clarify, then, why shifts in World Bank policy are not likely on their own to be sufficient to change conditions in the Third World it is perhaps useful to outline the elements and interactions involved in the underdevelopment spiral.

The elements of the syndrome are straight-forward. They include:

[Elements of the Underdevelopment Spiral]

- the expansion of cash-crop agriculture in the Third World
- the secular decline of real prices of Third World commodities in world trade
- the growth of cash exchange, collapse of local artisans and expanded merchandising of European manufactured goods.
- displacement of indigenous food crops by exogenous, hybrid, or petro-intensive cultivars
- the decline of small-hold agriculture and increase of "landless peasants"
- the movement of Third World populations from rural to urban areas
- demographic expansion in Third World populations
- the industrialization of agriculture and overproduction in industrialized nations
- changes in local weather and micro-climate patterns
- local and regional food shortages and the growth of international food trade and aid
- destruction of agricultural or pastoral lands through overgrazing, loss of topsoil, salinization, and flooding, and waterlogging
- the fitful but secular increase in the price of petroleum and petroleum products
- the long-term increase in relative prices of manufactured goods
- the growth of Third World indebtedness
- the expansion of bureaucracies, the collapse of public services and the growth of corruption

Added to this is a further set of elements which are not always present in every Third World circumstance. When they are, however, they tend to accelerate the pace of the spiraling interaction of the above elements. These added elements come into play when peasantries seek to arrest the underdevelopment spiral, and take matters into their own hands. Typically this involves attempts to: 1) seek to resist direct government exactions in one form or another; 2) seek better trade terms for items they produce or 3) seek control over arable land in order to pursue autonomous farming. If these peasant movements are countered by the state or by other classes acting on their own, the following added elements can come in to play:

[Added Elements in Exceptional Cases]

- the escalation of conflict in rural areas, diverting efforts from agricultural production
- the growth of an international arms trade, costing further drains on foreign exchange
- the outright destruction of crops, villages, and ground cover through ground combat, bombing, chemical defoliation or purposeful torching of biota to destroy an opponents's means of securing shelter, food or a livelihood.[22]

These latter elements are usually present only in extreme circumstances, where the former elements have re-reinforced one another for years, decades or generations. For general purposes, therefore, it is possible to set these obvious cases of environmental destruction aside for the moment to concentrate on the former elements and examine how they interact to produce the steady and seemingly irreversible cycle of environmental decline in the Third World.[23]

The first thing to note about the interactions between the elements is that although they are presented above in a specific order, no particular order is needed. Each element reinforces the aspects of the other elements in cyclical and perpetual interaction, approaching what systems ecologists might call a "positive feed-back" mechanism. This means that analysis can begin with any element and proceed through all the others. The links between them all strengthen themselves as the elements become more pronounced. Different academic professions will, no doubt, choose different points from which to start analyzing the links between the elements. Thus, economists may wish to begin by talking about the declining price of agricultural commodities, whereas a demographer might begin with the population explosion while a sociologist starts with Third World urbanization patterns. Soil scientists will probably talk of wide-scale erosion while ecologists might well begin with the massive transformation of the agricultural landscape, and journalists might choose to focus on massive corruption or bureaucratic incompetence.[24] Since all of these processes are going on simultaneously in a self-reinforcing manner, just where one begins the analysis of connectedness is not crucial to understanding the underlying dynamic of the whole process so long as the interaction of all elements is kept clearly in mind.

Post-War Africa: A Case-Study in Ecological Devastation:

For purposes of providing a brief illustrative narrative of how the phenomena are linked we can begin with the post-World War II expansion of cash cropping in the Third World.[25] Throughout Africa and much of the rest of the Third World during the colonial period rural regions became accustomed to imported manufactured goods that had become essential for their households or their agricultural pursuits. Axes, machetes, hoes, pots, cotton cloth, and a whole sundry of petty manufactured goods from matches to karosene lanterns had penetrated into rural regions during the early years of colonial rule. At the same time these regions had become accustomed to producing agricultural commodities like peanuts, coffee, cocoa, and cotton to earn the money to purchase these petty manufactures.

During the World War, however, two simultaneous phenomena occurred: first, the supply of European manufactured imports was cut off by scarce or non-existent shipping under wartime conditions. This raised the price of imports considerably, and for some time many goods simply were not available at all. The need for the goods upon which local households had come to depend remained pronounced, however, and in the process a considerable pent-up demand began to grow for European goods throughout the Third World. The second major phenomena, again due in part to wartime stingencies and problems of shipping, was that agricultural commodities produced for sale exceeded shipping capacity, and thus their price dropped in local markets. These combined phenomena created considerable pressure for change in colonial economic circumstances in the immediate post-war period.

With the removal of the wartime shipping problems in the late 1940s and 1950s there ensued a boom period of economic expansion that no precedent in previous colonial history. The colonial administrations usually contented themselves to building roads and public works infrastructure while maintaining public order, but apart from these roles they needed to do little positive planning to encourage economic growth in this period. The pent-up peasant demand for manufactures and their capacity to their own expand production to earn more cash for these purchases was in itself sufficient to enable most colonial regions in Africa to witness a remarkable trading bonanza fueled by this rapid cash-crop expansion.

The cash-crop boom, although sustained for several years, remained nevertheless an inherently unsustainable phenomena, ironically because of its very success. So many peasants in the Ivory Coast, Ghana, Nigeria and the Cameroons turned to cocoa and coffee production that the mounting supply was exceeding world demand, and the prices for these commodities began to fall in real terms during the 1950s. As Brazil and East African countries like Kenya entered the ranks of coffee and cocoa producers the purchase prices of these commodities declined even further over time.

This engendered the classic syndrome known to economists as the "primary producer's squeeze." The dilemma went something like this. Oversupply was at the root of the declining purchase price for these commodities, and it could be argued that the peasants should refrain from producing further cocoa or coffee or the like until the supply declined and the prices came up to a level of their liking. While this might be a theoretical possibility, in practical terms it was never really an option for most peasants.

The reasons for this were simple: peasants had already made the infrastructural investment in the cocoa and coffee plantations. The trees could not simply be turned on or off like a faucet when prices proved favorable. On the contrary, these commodities were harvested annually and would be wasted entirely if not sold within a fairly short time of the annual harvest. If the weather and pest problems were manageable and a region experienced a particularly good production year, they were faced with the irony of a locally glutted market at harvest time and a correspondingly depressed purchase price. In the face of a depressed price, a peasant with fixed or escalating costs or other demands upon his income had basically two options open to him. Either he could chose to expand the scope and scale of his production to maintain or enlarge his income to meet his growing needs, or alternatively he could leave cash-crop farming and go to the city in a hopeful search for non-agricultural work. Such was the squeeze most peasants faced in one form or another.

A third option -- that of engaging once again in food-stuff agriculture -- was largely precluded at the time by the impact upon Africa and other Third World areas of the pattern of agricultural overproduction from the Western countries, particularly the United States. In the post-war era, the United States farmers began to mechanize agriculture, purchasing tractors, fertilizers and pesticides to substitute for the declining manpower engaged in on-farm production. The initial results of this petro-subsidized agriculture were very impressive in volume output, and since oil prices at the time reflected only minimal extraction and transport costs surplus agricultural production from the United States began to appear to the world at large as an answer to momentary or even more long term shortages in local food production.

Through both aid and trade channels, the United States sought actively to export its agricultural surpluses. Since most capital cities of Third World countries were constructed as ports or trans-shipment centers during the colonial period, it became very easy and even appeared wise to purchase American grain surpluses to feed growing urban populations in the Third World. When disasters like floods, earthquakes or typhoons hurt the remaining local agricultural systems, U.S. aid agencies provided relief supplies of food at cost through PL 480 funds and the "Food for Peace" program. In the face of the massive arrival of food surpluses from the industrial world, it became clear that peasant farmers -- often situated in remote rural areas with poor transportation links to the cities -- were not generally able to engage in profitable competition with Western farmers and the state apparatus of industrial nations which together had the power to pursue agricultural "markets" in the Third World.[26]

The cyclical and self-perpetuating nature of the problem started to become apparent by the early 1960s. Peasants, trying to stay afloat economically, began to devote more and more of their arable land to cash-cropping which, in turn, provided less and less in relative terms, the more they produced. In the process, with relatively less land and labor devoted to foodstuff agriculture in Africa, not only its urban areas, but also major rural regions became dependent from the 1960s onward on substantial imports of foreign surpluses. According to one observer, "food imports rose from 4 million to 24 million tons during the 1970s. By 1985 the continent was importing two-fifths of its food supply and about a third of its people depended wholly or partly on imported food."[27] Meanwhile, those peasants or their children who had left the village began to swell the ranks of the urban areas with no real prospects for steady wages.[28]

Politically this was a volatile situation, for hungry urban populations could prove to be explosive. Quite understandably, then, urban-based political elites tended to continue to buy political tranquility in the short run, by purchasing food from the cheapest source -- the surpluses of Western industrial countries. In order to purchase this foreign food, the state exhorted its cash-cropping peasants to produce ever greater quantities of export commodities so that it could obtain the foreign exchange for the increasingly necessary food purchase transactions. While exports expanded, commodity prices dipped with oversupply, and foreign exchange became scarce, despite expanded output. In this circumstance the states concerned either had to seek food aid or incur foreign debt to purchase the food upon which they had come to depend. Indebtedness proved to be only a short term solution, for with the increase and unsteady fluctuation of interest rates, many African countries soon found themselves having to devote much of their foreign exchange earnings to servicing these debts. The overall debt burden for the continent rose from $14 billion in 1973 to an estimated $125 billion in 1987.[29]

The rapid rates of urbanization which contributed to the pattern of collapse in local agriculture had yet another demographic impact on the rural areas. Faced with the departure of the young, able-bodied members of their households, families often resorted to having several children in the hope that some would remain to undertake the ever more demanding cash-crop work.

Collectively this translated itself into a rapid spurt in population growth, particularly as this period also witnessed the arrival of rudimentary medical facilities and the equipment for clean water supplies in rural areas. Both of these latter phenomena contributed to the decline in infant mortality, and the result over time was a rapid rise in absolute numbers in rural areas.

During the 1950s and 1960s those portions of these growing populations that remained on the land greatly expanded the areas devoted to agricultural activity without substantially changing the technologies applied to production. The result was enormously taxing upon the land itself and the environment in general. In bush-fallow systems of land usage fallow periods were shortened or eliminated altogether, and on the thin and nutrient poor soils this new pattern of usage rapidly exhausted arable lands. In addition, previously undisturbed forests began to be cleared under a two-fold pressure. First, the relative decline of commodity prices for coffee and cocoa left the state short of foreign exchange, and it began to extend rights to timber concessions for cutting and exporting tropical hardwoods as a means of shoring up sagging trade balances. Secondly, peasants hoping for new cash-cropping opportunities or in those in search of fertile land for growing food began to encroach upon remaining zones of uncut forest.

Removal of large portions of tropical forest cover and conversion of whole regions to cropland and grassland had the effect of changing the nature of the local hydrological regime. Water which previously was held in the canopy or locked in the root systems of vegetation in the forest would subsequently run off at accelerated rates with little or no ground cover left of hold it. Dramatic flooding became a feature of the rainy season in many parts of Africa, and considerable topsoil was lost to sheet and rill erosion in this manner. This further depleted the agricultural potential of the land. The deterioration became particularly acute in those areas subject to annual food-stuff production. By comparison, the land devoted to plantation cash-crop agriculture largely retained and in some cases enhanced its fertility. Over time the disparities between the land devoted to export production and those remaining for food production became all the more pronounced. Some regions of African rural areas have been so overgrazed, overcropped and eroded that it is doubtful that agriculture can continue on these soils for much longer without considerable imported subsidies to rebuilt soil structure and fertility.

Soil fertility is not all that is involved in this cycle of decline. The rainy season floods are not infrequently followed in local areas by dry season droughts. The water in the annual hydrological cycle is not maintained in watersheds to be drawn upon over the full year. Instead it rushes though the region, often taking all before it in the rainy season, only to leave sun-baked clays and dried up wells in the ensuing months. In areas where soil depletion and the change of ground cover has proceeded to decline for decades, it is even possible that local weather patterns can shift over time.

While the global climate fluctuates over periods and with dynamics that are not yet fully understood, it seems nonetheless the case that regional weather patterns or micro-climates can be significantly altered in a matter of generations or even decades if major shifts in land and water use are engendered by new patterns resource exploitation. Mankind can foster the processes of desertification by pursuing unwise development strategies or by encouraging peasants to overtax their land and water resources. While there seems to be a periodic pattern to drought in Africa, there may well be an anthropogenic component to the weather anomalies that the continent has witnessed over the last two decades.[30]

In cases of local or regional drought, populations that have become dependent upon purchasing food in exchange for cash can find themselves short of food for reasons well beyond their control. Fluctuations in the price of oil affect both international shipping and internal transport costs of food as well as the total foreign exchange profile of individual countries. Thus, the fitful increases in oil prices have been translated in local terms in Africa into an increase in the price of imported food and occasionally a pattern of seasonal or chronic shortage. This is compounded as the world market in grains fluctuates with the purchasing habits of major industrial countries. When Soviet, Chinese or Indian harvests are poor and Western grain surpluses are bought up on the international market, African countries find themselves in the face of prices beyond their purchasing power. As we have seen in recent years, food shortages can become acute and famine widespread in these circumstances.[31]

Crash efforts to develop "modernized" agriculture based on "green revolution" technology are offered by Western agricultural experts in the wake of these famines to meet the urgent and evident need for expanded food production, but in ecological terms these kinds of development projects should be examined carefully before they are adopted. Generally these technological packages are based upon "high-yield-varieties" (HYVs) of crops that have been selected to respond will to a combination of fertilizers and pesticides designed for their needs. In this regard the HYVs are more appropriately labeled "high response varieties" (HRVs). They respond well to the petrochemical subsidies which they were engineered to use, but on their own their performance may well not even equal that of traditional varieties.[32] When one considers the probable rise in cost of the petro-chemical additives needed to make them produce along with the infrastructural investments required for irrigation systems, storage systems and mechanized equipment associated with the "modernized" agriculture, it is not clear that the choice of these technologies is a wise one for the Third World in the long run.

On the contrary, similar investments in roads, marketing facilities, or land directed towards traditional crops may well prove over the long run to be better spent than the money devoted to the alluring promise of "miracle" crops. The real costs of HRVs become apparent only over a period of several years or decades as it becomes clear that adopting this kind of agriculture amounts to transforming bio-sustainable solar-based agricultures to petro-subsidized systems of production.[33] In the face of declining petroleum supplies it is questionable whether development schemes based upon increasingly energy-intensive technologies can be sustained much longer.

Another element of the underdevelopment spiral leading to chronic environmental degradation in Third World rural areas is the problem of undernutrition; malnutrition and resulting spread of chronic and epidemic disease among the population. Undernourished and malnourished populations generally experience higher infant mortality rates than well fed populations. Increased infant mortality can lead to the impulse to have more, not fewer, children if it engenders a generalized anxiety on the part of peasant parents to be able to supply their labor needs and means of support in their elderly years.

In general, fertility rates decline *only after* mortality rates have begun to decline for a noticeable period among peasant populations. As long as disease patterns or economic hardships assure that mortality remains high or actually increases, fertility itself is likely to remain high as well. There now seems to be no assurance that the Third World as a whole will be likely to experience the same kind of "demographic transition" that characterized the population history of Europe during the last several centuries of its economic development precisely because deteriorating conditions in the Third World may keep mortality levels high. Chronic famine in Africa has made this dramatically apparent.

Beyond the question of mortality, however, and its indirect effects upon fertility, there is the problem of endemic morbidity -- the debilitating phenomena of chronic or epidemic disease. In agricultural societies dependent upon manual labor, chronic levels of disease seriously reduce productivity over time. This is particularly true at serious labor demand periods when food is in short supply. Poorly fed populations can be either too sick or too weak to undertake the necessary extra work needed to adopt conserving measures in their cultivation practices or even to assure a proper preparation of their fields for planting. Nearly all the peasants I have worked with would like to be able to plant on larger surfaces than they do, but they are either not able to mobilize the labor or not capable of undertaking the extra work themselves. A peasant who repeatedly becomes sick or incapable of planting his own food is in a dangerously precarious position.

As the colonial regimes recognized, investments that improved public health were well worth their expense because of the benefits to rural production they would engender. Conversely, the post-colonial governments that are short on investment funds and do not provide adequately for maintaining public health in rural areas are likely to witness a measurable decline in agricultural productivity over time. In regions of East Africa now struck by AIDS, agricultural production has been reduced appreciably. More pervasively a drug resistant form of malaria is beginning to gain hold in parts of Kenya, weakening populations and reducing work capacity.

As circumstances in rural areas become more desperate, some peasants may leave their regions in search of better conditions elsewhere. When this is done individually it often takes the form of rural-urban migration. In areas where urban employment is not encouraging, however, this can take the form of rural-rural migration of laborers, either as seasonal or permanent workers in new lands. When large changes occur in the development potential of whole regions due to drought or irreversible ecological deterioration, whole communities have been seen to move. At the height of the drought in Chad 500,000 people were said to be on the move with all their possessions and livestock from northern regions to southern regions of the country.

These massive migrations of population were at one and the same time a symptom and a cause of environmental degradation. The movement of cattle stock into more restricted ranges threatens the accommodating territory with overgrazing and places pressures on the available water supply. Once populations in this migrant state become dependent upon relief supplies of food aid in order to eat, the major problem becomes how to design agricultural systems that can help them re-establish their agricultural autonomy, usually on a severely impoverished resource base. Often this cannot be done, and today there are more than 5,000,000 people on the African continent who live in refugee or relief camps of some sort.

Whether in refugee camps or in the expanding shanty towns surrounding major urban agglomerations the growing populations, up-rooted from productive

Enduring Lessons from Anthropology and Archaeology:

When the underdevelopment spiral observed by contemporary field-anthropologists is fully articulated, it is difficult to keep one's bearings in assessing the lessons that have been learned from contemporary Third World circumstances. One is beset with "doomsday-ers" on the one hand who are predicting imminent collapse of all peasantries and "sooth-sayers" on the other who think that simply new doses of capital and technology can set the Third World on the road to permanent prosperity. Neither extreme seems reasonable.

In assessing our contemporary situation, then, it is perhaps useful to keep the historical and archaeological record in mind, for we are dealing here with large-scale and potentially long-term problems. While numeric precision in forcasting may not be possible, several clear patterns emerge from this long-range perspective. In the first place, while we do not know how far current populations are from reaching the earth's carrying capacity, it seems clear that two things are happening: 1) the carrying capacity of at least some local environments is declining measurably; and 2) the population (and hence resource-use) load is simultaneously increasing. [See graphic presentation in fig. 1, appended.]

Beyond this, it is not fully clear what will happen if both of these trends continue on their current trajectory [See fig. 2]. Nor is it clear precisely what time-frame is remaining in which we must as a society and a world community find solutions to these problems.

Two general phenomena complicate the issue of achieving an adjustment between expanding populations and declining resources. First, is the problem of perception. In general, it is recognized that there are upper limits involved in the amount of information that an individual or a society can successfully absorb and act upon. After a certain threshold as the environment becomes more complex, a society's ability to recognize or use information about its circumstance effectively declines [See fig. 3]. It is as though things become too complicated to know what is happening. This may well reflect our current position with reference to the Third World. In reality ecological problems are global in scope, and we will need to develop a matching degree of perception. Tropical deforestation affects both local weather and world-wide climate patterns. Food from Iowa feeds both Boston and Burundi. Currently, it is in the Third World that global ecological crises become most pronounced, but it would be a major mistake of perception for Western leaders to assume that the problems in the Third World are merely the Third World's problem.

A second threshold problem seems to be reflected in the general pattern of cooperation observable in societies faced with ecological stress [See fig. 4]. Initially, as ecological stress mounts, so does cooperation. Society members express a common will to overcome difficulty. After a certain threshold of stress, however, this cooperation degenerates, and open conflict can result. Current famines in Africa are often said to result as much from patterns of ethnic or civil strife as they do from problems of rainfall. One troubling aspect of these threshold phenomena is that just where these levels are is not clear. It would seem that there is a great deal of inter-cultural and inter-societal variation in these things, and the vision of public leaders may well play a key role in determining the threshold levels.[35]

Broadly speaking, there seem to be two possible patterns that emerge from the evolving trajectories of population and carrying capacity. First, it is possible that a stable adjustment can be achieved [See fig. 5]. This would be possible if the entire population concerned perceives the problem of adjustment as a real one, and simultaneously cooperates to achieve stabilization. Such a resolution implies that the society can exercise a remarkable degree of self-imposed restraint.

An alternative resolution of current and future trends involves the phenomena of ecological "overshoot" and subsequent collapse [see fig. 6]. This would most likely occur either if the society did not perceive the problem at hand or if it did not succeed in achieving cooperation in a transition to a stable adjustment. The time lag involved between the overshoot and subsequent collapse is not at all clear. Nor is it clear just where we are located at the current moment in either of these two possible scenarios. Some scientists feel that we may already have exceeded the earth's capacity to sustain present populations on a permanent basis.[36] We are perhaps just beginning to witness the phenomena of collapse in indicative catastrophes ranging from repeated Bangladesh floods to recurrent African famine.

Whatever the time scenarios prove to be, there are very definite signs of difficulty emerging from the overall evolution of the global food system in recent history. Briefly put, Western agriculture, and American agriculture in particular, has achieved enormous levels of output through a pattern of substituting human agricultural labor with fossil fuel driven machines. The result is that while there has been a substantial decrease in the human labor used on American farms during this century, there has been an overall increase in the energy subsidy required to obtain one calorie of consumable food in the American food system [see figs. 7 and 8].[37]

Moreover, the vast majority of the energy subsidy provided to the food system in the United States is not reflected in the amount food energy consumed [see fig. 9]. Finally, the long range trend from the 1920s until the present suggests that increases in energy inputs into the system have been approaching a point of diminishing returns interms of overall food production. In other words, if this trend persists, future increases in food output will require even higher rates of energy inputs [see fig. 10]. This is a disturbing circumstance, particularly in view of the decline in food self-sufficiency of large numbers of Third World countries.

In order to survive in the coming decades we will need to engineer the transformation of global agro-ecosystems away from petro-based and toward bio-sustainable forms of agricultural technology. We cannot predicate our agriculture on fossil fuels and expect that agriculture to outlast the supply of this resource. Unless steps are taken in the near future to reverse the rapid increase in global dependence upon petroleum-based agriculture, we can expect wide-scale dislocations including famine, ensuing disease and open armed conflict to emerge on an expanding scale as supplies of that non-renewable resource decline and competition to control its use intensifies. We live in a highly industrialized, urban culture, but it is important to remember that there is no such thing as a "post-agricultural" society. Policy decisions concerning agriculture, our environment and the future provision of public works (water projects, transport systems, land-use patterns, etc.) need to reflect this fundamental truth. Cultures that failed to understand this in the past have proved to be short-lived. We will be no exception to this pattern.

It would be extremely foolhardy in the coming years to shape our environment and continue to construct the infrastructure of our society in a manner that commits global agricultural production irretrievably to a non-renewable resource. This is a recipe for extinction. With current patterns of resource-depleting, petroleum-based agriculture it is as if we are traveling down a dimly lit, one-way street at 90 mph, and we are just beginning to realize that the sign post we passed a while back said "Dead End." Action to avert future catastrophe in this circumstance must begin now on the part of all responsible political leadership. The remaining transition period cannot be very long [see fig. 11]. This is not a party-political issue. Nor is it simply a problem for the welfare of particular nation-states. It concerns our survival as a species.

Notes

1. Vice President Bush, while talking of toxic waste and this summer's beach pollution, recently announced on the shores of Lake Michigan that 1988 is the year that our environment began to "speak back" in response to the abuse it has suffered. In reality, the environment has been "speaking back" to man for centuries, indeed millennia. What is striking in retrospect is our seeming inability or stubborn refusal as a culture and perhaps even as a species to hear what it has been saying.

2. A useful summary account of ancient ecological problems can be found in, J. Donald Hughes, **Ecology in Ancient Civilizations** (Albuquerque, U. of New Mexico Press, 1975). There has been some debate among archaeologist as to the relative importance of human agency or environmental change as the primary factor in explaning accelerated patterns of soil erosion in the circum-Mediterranean over historic time. While climate theories were favored at an early date, theories stressing anthropogenic activity are gaining ascendency. "Recent work around the Mediterranean has tended to favour human rather than climatic factors as the cause of the dramatic accumulations of sediment which took place in so many areas." Kevin Greene **The Archaeology of the Roman Economy** (Berkeley, U. of California Press, 1986), p. 85. See also S. Judson, "Alluviation and Erosion," in E. Fentess, et. al., **Excavations at Fosso della Crescenza 1962** (Rome, 1982), [Papers of the British School of Rome, No. 51] pp. 58-101; and Claudio Vita-Finzi **Archaeological Sites in Their Setting** (London, 1978), especially, pp. 8 and 11-13.

3. See H. W. Lawton, and P.J. Wilke "Ancient Agricultural Systems in Dry Regions," in A. E. Hall, G. H. Cannell, and H. W. Lawton, (eds.) **Agriculture in Semi-Arid Environments** (New York, Springer-Verlag, 1979), pp. 1-44. Popular, if somewhat dated accounts include: Edward Hyams, **Soil and Civilization** (New York, Harper and Row, [1952] 1976); and Vernon Gill Carter and Tom Dale **Topsoil and Civilization** (Norman, University of Oklahoma Press, 1976).

4. See for example, W. Groenman-van Waateringe, "The Disastrous Effect of the Roman Occupation, in R. Brandt and J. Slofstra, (eds), **Roman and Native in the Low Countries: Spheres of Interaction** (Oxford, British Archaeological Reports, s184, 1983), pp. 147-157; and Claudio Vita-Finzi, "Roman Dams in Tripolitania," **Antiquity,** 35, (1961), pp. 14-20; and Z. Naveh, and J. Dan "The Human Degradation of Mediterranean Landscapes," in. F. Di Castri and H. A. Mooney (eds.), **Mediterranean Type Ecosystems** (New York, Springer-Verlag, 1973), pp. 373- 390.

5. The Western historical experience has been exceptional in at least two respects: first, no other civilization seems to have replicated this experience of outward expansion on a comparable scale; and secondly in no

other period of history does there appear to have been this much exploration, outward migration, trade and conquest in such a comparatively short interval of time.

6. See particularly: Alfred W. Crosby, Jr. **The Columbian Exchange: Biological And Cultural Consequences of 1492** (Westport, CT., Greenwood Press, 1972); as well as his **Ecological Imperialism: The Biological Expansion of Europe, 900-1900** (New York, Cambridge University Press, 1986). For a detailed account of the ecological impact of early colonial presence of Europeans see, William Cronon, **Changes in the Land: Indians Colonists, and the Ecology of New England** (New Hork, Hill and Wang, 1983).

7. For an overview of the patterns of ecological interaction that characterize colonial circumstances see: Timothy C. Weiskel, "Agents of Empire: Steps Toward and Ecology of Imperialism," **Environmental Review**, 11, 4 (1987), pp. 275-288.

8. For a discussion of the impact of the frontier experience upon ecological consciousness in America see, Timothy C. Weiskel, "Rubbish and Racism: Problems of Boundary in an Ecosystem," **The Yale Review**, (Winter, 1983), pp. 225-244.

9. Edward Goldsmith, "Is Development the Solution or the Problem?" **The Ecologist**, 15, 5/6,(1985), p. 210.

10. A number of global "commissions" have been constituted to investigate the widening gap between the "developed" and the "underdeveloped" world, ever since the impact of the oil price hikes began to signal a global economic recession in the mid 1970s. Most notable of these were the two commissions chaired by Willie Brandt, the former West German head of state. The first commission report was finished in 1978 and the second in 1983. See, Brandt Commission - Independent Commission on International Development Issues **North-South: A Program for Survival** (Cambridge, M.I.T. Press, 1980); and Brandt Commission **Common Crisis: North-South: Cooperation for World Recovery** (Cambridge, M.I.T.Press, 1983). For a critique of the Brandt Commission approach see, Teresa Hayter, **The Creation of World Poverty: An Alternative View to the Brandt Report** (London, Pluto, 1981).

In addition, the United States Department of State and the Council on environmental Quality issued in 1980 a document called **Global 2000: A Report to the President** which detailed environmental and resource supply trends throughout the world and provided suggestions for future policy.

Most recently, the United Nations commissioned Gro Harlem Brundtland, the Prime Minister of Norway, to head a study group on global ecological and economic issues. Ironically, their report was issued on 19 October 1987 -- the day of the largest stock-market crash in American history -- and as a result, the dramatic public impact it may well have had were it to have been issued a week earlier or later was largely eclipsed by the public attention given to the stock-market events. In addition, it is probably true that since it was a report from a U.N. commission, Americans may well have ignored its message. In recent years top public officials in the United States have held the U.N. and its service organizations like U.N.E.S.C.O. and F.A.O. in open contempt, largely because of the continuous criticism from Third World members leveled at American policies in the global arena. American leadership seems to have proceeded on the operative assumption: "if you don't like the news, ignore it." It is not clear this is a wise strategy in the context of worsening global ecological problems that require cooperation for solution. The report itself deserves wide public consideration and debate. See World Commission on Environment and Development [Brundtland Commission] **Our Common Future** (New York, Oxford University Press, 1987).[Brundtland Commission Report].

11. Robert Sangeorge, "Tropical Forests Face Destruction," **UPI News Wire Dispatch**, 23 March 1984, 1:49 pm. A "closed forest" as land where trees shade so much of the ground that a continuous layer of grass cannot grow.

12. Ibid., **UPI News Wire Dispatch**, 23 March 1984, 1:49 pm.

13. Notable contributions have come from Norman Myers, whose study for the National Research Council and more popular works have done much to draw broad public attention to the problem. See: Norman Myers **Conversion of Tropical Moist Forests** (Washington, D.C., National Academy of Sciences, 1980); and his **The Primary Source: Tropical Forests and Our Future** (New York, Norton, 1984). In addition Earthscan has issued an action-oriented summary of what can be done. See Judith Gradwohl and Russell Greenberg, **Saving the Tropical Forests** (Washington, Earthscan, 1988).

The World Resources Institute in coordination with the World Bank and the UNDP has drawn up what it calls a "call for action" to help stop the loss of tropical rainforests. See: **Tropical Forests: A Call for Action, Pt. I. The Plan; Pt. II. Case Studies;** and **Pt.III Country Investment Profiles** (Washington, World Resources Institute, 1985). As one might expect, however, this proposal has come in for considerable criticism by those who argue that the World Bank's proposed solutions favor the very kind of development efforts that have devastated rain forests in the first place. In this regard see: Magda Renner, "A Critical Review of Tropical Forests: A Call for Action," **The Ecologist**, 17, 4-5, (1987), pp. 150; and Vandana Shiva, "Forestry Myths and the World Bank: A Critical Review of Tropical Forests: A Call for Action," **The Ecologist**, 17, 4-5, (1987), pp. 142-149.

14. **UPI News Wire Dispatch**, 8 June 1987, 6:20 pm.

15. Elizabeth Love, "Panama Canal's water supply threatened, report says." **UPI News Wire Dispatch**, 13 April 1987, 7:47 am.

16. Ibid., **UPI News Wire Dispatch**, 13 April 1987.

17. "Protesters say World Bank ruins forests," **UPI News Wire Dispatch**, 29 September 1986, 2:31 pm; and Brad Smith, "Preserving rain forests: Conservationist coalition seeks to save rain forests." **UPI News Wire Dispatch**, 24 February 1987, 2:44 pm.

18. Ibid., **UPI News Wire Dispatch**, 24 February 1987.

19. See Tyler Bridges, "The Rain Forest's Road to Ruin?; Ecologists Decry World Bank Role in Building Brazilian Highway," Washington Post, 24 July 1988.

20. Craig Webb, "World Bank launches new pro-environment campaign." **UPI News Wire Dispatch**, 5 May 1987, 4:41 pm. See also, Constance Holden, "The Greening of the World Bank," **Science**, 240, (17 June 1988), p. 1610.

It is particularly significant that a long-standing critic of growth economics has recently been named to work on World Bank policy issues pertaining to Latin American. Herman Daly, author of **Steady-State Economics**, and long-time critic of conventional economic growth theory is currently working at the World Bank. Analysts of Bank policy regard Daly's appointment as a remarkable reversal, but it remains to be seen to what extent Daly's perspective can prevail in a bureaucracy as accustomed to growth-oriented criteria of success as the Bank has proved to be in the past. See, Constance Holden, "A Heretic Amid Economic Orthodoxy," **Science,** 240, (17 June 1988), p. 1611.

21. This question is asked directly in an extended article by Edward Goldsmith, "Is Development the Solution or the Problem?" **The Ecologist**, vol. 15, 5/6, (1985), p. 210-219.

22. In taking into account the environmental costs of various development strategies, scholars have tended to neglect the ecological impact of open conflict that is predictably unleashed when particular development policies are pursued. This is a curious omission, and marks a peculiar kind of blind spot in assessing development strategies. Not all concerns are similarly myopic. Businesses involved in Third World agriculture projects regularly include considerations of "security" as part of the operating costs they need to incur to protect their investments. If peasant resistance or sabotage to these projects becomes too expensive, the enterprise nearly always calls upon the state military apparatus to undertake the effort and expense of suppressing peasant opposition. The costs of repressing peasant revolts are readily calculable in terms of munitions and manpower, but the costs to the peasants's environment or the world's ecosystem of doing so are usually overlooked as an "externality" in the whole process. If we are to develop a reasonable means of assessing the environmental costs of development strategies, we should try to include this "externality" in our calculations.

The policy implications of undertaking these economic calculations would be significant, for whatever the economic virtues of pursuing capitalist development strategies in regions like Central America, the ecological destruction involved in crushing peasant rebellions or launching "contra" insurgencies is massive and needs to be counted as a real cost in any cost-benefit analysis of any proposed development strategy.

23. The potential ecological impact of nuclear war has attracted much attention recently, but all kinds of war are clearly costly to the environment. An examination of the ecological effects of "limited" wars, particularly those against peasantries in the Third World can begin with the Stockholm International Peace Research Institute's study, **Warfare in a Fragile World: Military Impact on the Human Environment** (London, Taylor and Francis, Ltd., 1980) and Arthur H. Westing, (ed) **Herbicides in War: The Long-Term Ecological and Human Consequences** (London, Taylor and Francis Ltd., 1984). These internationally commissioned reports have largely been ignored in the United States, perhaps, once again, because current American political leadership finds it difficult to accept responsibility for the chemical warfare techniques used in recent wars in Indochina and advocated by some for current use in Central America. Indeed, given its opposition to compensation for alleged "agent orange" disabilities among its own veterans, current administration reluctance to examine these issues publicly is perhaps understandable if not excusable.

24. Much of the debate between social scientists analyzing environmental crises in the Third World world is over the question of where to ground the *fundamental* starting point for analysis. From the perspective of systems thinking adopted here, this kind of debate is as pointless as it is fruitless.

Such debates often deteriorate into "which is the better social science? economics? demography? sociology?, etc". The point we wish to emphasize here is that no particular perspective deserves priority, but all must focus on the connectedness, the fundamental inter-relatedness of these phenomena if an effective means of addressing our environmental crises is to be developed. See conclusions below.

25. For a more extended discussion of a particular case-study see, Timothy C. Weiskel, "Toward and Archaeology of Colonialism: Elements in the Ecological Transformation of the Ivory Coast," in D. Worster (ed.), **The Ends of the Earth** (Cambridge, forthcoming).

26. For a summary of U.S. export food policy see the study by the French scholars, Alain Revel and Christophe Riboud **American Green Power** (Baltimore, Johns Hopkins U. Press, 1986). For a critique of the impact of U.S. surplus exports see Frances Moore Lappé, Rachel Schurman and Kevin Danaher **Betraying the National Interest** (San Francisco, Institute for Food and Development Policy, 1987). For a discussion of the various impacts of foreign food dependence see: Timothy C. Weiskel, "A Public Policy for Plant Genetic Resources," **Worldview**, 23, 10 (October, 1980); and "Food, Famine and the Frontier Mentality," **Worldview**, 12, 12 (December, 1981).

27. Jennifer Seymour Whitaker, **How Can Africa Survive?** (New York, Harper & Row, 1988), p. 18.

28. Urbanization is occurring at rates that exceed population growth in most of Africa, and at current rates experts estimate that fully 45% of Africa's population will live in urban or semi-urban areas of 4000 or more by the year 2010. The massive expansion of urban areas is not uniquely an African phenomena. Mexico City is already the largest city in the world and growing at a rate of 1 million per year. Asia will have 23 cities with populations of 5 million or more by the year 2000. See "Population Boom for Asian Pacific," UPI News, **7 June 1988, 17:47 pm.**

29. J. S. Whitaker, **How Can Africa Survive?**, p. 19.

30. On the interaction of human activity and climate see particularly, Richard W. Franke, and Barbara H. Chasin **Seeds of Famine: Ecological Destruction and the Development Dilemma in the West African Sahel** (Montclair, Allanheld, Osmun, 1980); Alan Grainger, **Desertification: How People Make Deserts, How People Can Stop and Why they Don't** (Washington, International Institute for Environment and Development, 1985); and Independent Commission on International Humanitarian Issues **Famine: A Man-Made Disaster?** (London, Pan Books, 1985).

31. Ecologists hesitate to make predictions, but circumstances in mid-1988 do not present a promising picture for countries that have become irreversibly dependent upon North American agricultural surpluses. The United States drought of 1988 has hit oat and corn harvests severely. In addition, China is experiencing a simultaneous drought, causing some observers to suggest that food surpluses may dwindle in the coming year. While the Soviet Union is predicted to have a bumper crop in 1988 and some South American countries are going to take up the slack in production experienced in the northern hemisphere, agricultural analysts are wary about the prospects for long-term food security on a global scale. See "Food experts study hunger in the midst of plenty," UPI News, **4 June 1988, 16:56 pm.**; "Drought May Sink

Grain Stocks," AP News, **26 June 1988, 15:32 pm. [Sunday]**.; Food-Threats, USDA Expert Sees Trouble Ahead," AP News, **10 July 1988, 4:12 am. [Sunday]**.; "Soviet-Harvest, Bumper Crop Seen For Soviets," AP News, **12 July 1988, 19:17 pm. [Tuesday]**.; and "Drought Is Boon To S. America," AP News, 22 **July 1988, 13:13 pm. [Friday]**.

32. For assessments of the shortcomings of the green revolution see Kenneth A. Dahlberg, **Beyond the Green Revolution: The Ecology & Politics of Global Agricultural Development** (New York, NY, Plenum Publishing Corporation, 1979);Tim Bayliss-Smith, and Sudhir Wanmali, (Eds.) **Understanding Green Revolutions: Agrarian Change & Development Planning in South Asia** (New York, NY, Cambridge University Press, 1984); Edward C. Wolf, **Beyond the Green Revolution: New Approaches for Third World Agriculture** (Washington, D.C., Worldwatch Institute, 1986). Worldwatch Paper No. 73; and Bernhard Glaeser, **The Green Revolution Revisited** (Winchester, MA, Allen & Unwin, Incorporated, 1987).

33. For critiques of the energy costs of petroleum-subsidized agriculture see Maurice B. Green, **Eating Oil: Energy Use in Food Production** (Boulder, CO., Westview Press, 1978); and John Gever, et. al **Beyond Oil: The Threat to Food and Fuel in the Coming Decades** (Cambridge, Ballinger, 1986). Concerning the deadly impact of pesticides necessary in petro-subsidized agriculture see David Weir, and Mark Schapiro, **Circle of Poison: Pesticides & People in a Hungry World** (San Francisco, CA, Institute for Food & Development Policy, 1981); David Bull, **A Growing Problem: Pesticides and the Third World Poor** (Oxford, OXFAM, 1982); and David Weir's latest work, **The Bhopal Syndrome: Pesticide Manufacturing and the Third World** (Penang, Malaysia, International Organization of Consumers Unions, 1986).

34. Widescale corruption in public office is often offered as an explanation for Africa's sad state of affairs, particularly by journalists. See for example, Xan Smiley, "Misunderstanding Africa," **Atlantic Monthly**, 250, (September 1982), pp. 70-80 and J. S. Whitaker, **How Can Africa Survive?**, pp. 48-52. On balance, corruption is far better understood as a symptom of systemic malfunction rather than as its basic cause. Nevertheless, the amassing of private fortunes in public office and their ex-patriation into foreign bank accounts accounts for a massive "capital flight" from many developing countries, and thus exacerbates the underdevelopment spiral.

35. The perception and stress models here are adapted from those presented by Charles D. Laughlin and Ivan A. Brady "Introduction: Diaphasis and Change in Human Populations," in **Extinction and Survival in Human Populations** (New York, Columbia University Press, 1978), pp. 1-48.

36. In this connection see the views of several emminent members of the National Academy of Sciences as reported from a conference of biologists at Stanford earlier this month, "'Population bomb' still ticking," **UPI News**, 3 Sept. 1988, 11:57 am.

37. The graphs in figures 7-10 are from: John S. Steinhart and Carol E. Steinhart, "Energy Use in the U.S. Food System," **Science**, 184, (19 April 1974), pp. 307-316.

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Fig. 1. Current Circumstance

[Declining Carrying Capacity (K) and increasing population (p). We do not know how wide the separation between the two is, but we do know that one is increasing and the other declining, at least in localized regions.]

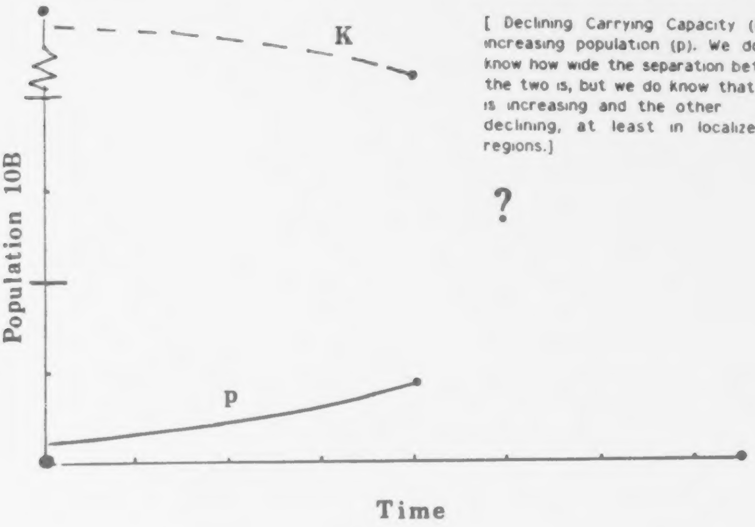
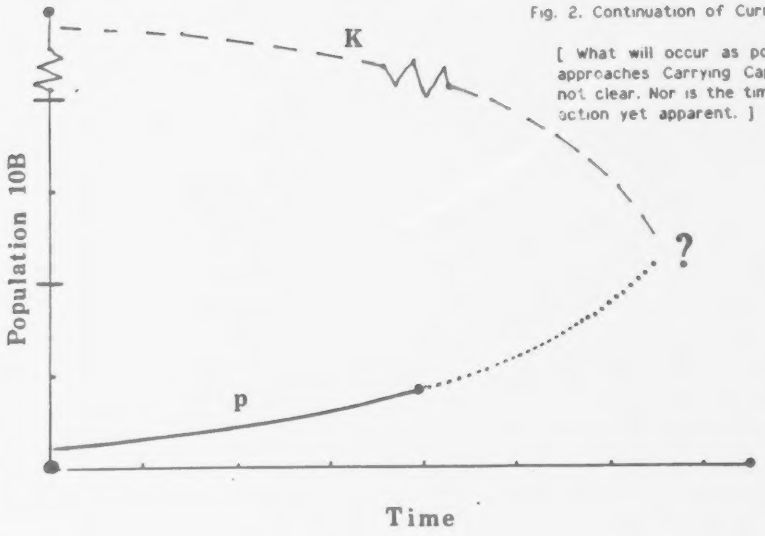


Fig. 2. Continuation of Current Trends

[What will occur as population (p) approaches Carrying Capicity (K) is not clear. Nor is the time-frame for action yet apparent.]



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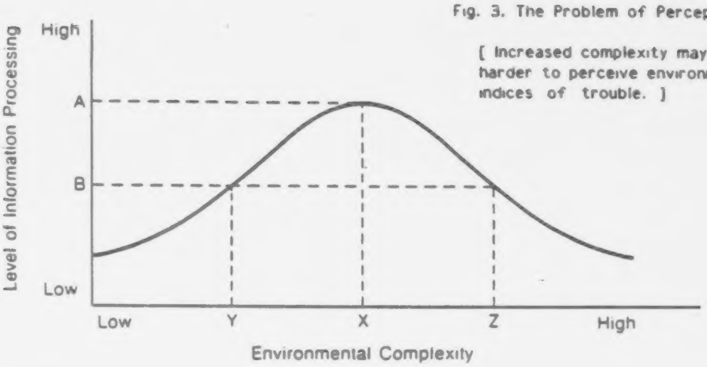
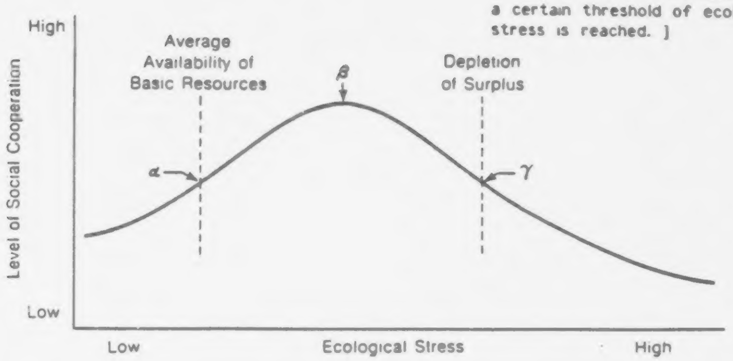


Fig. 3. The Problem of Perception

[Increased complexity may make it harder to perceive environmental indices of trouble.]

Fig. 4. The Problem of Cooperation

[Cooperation tends to decline after a certain threshold of ecological stress is reached.]



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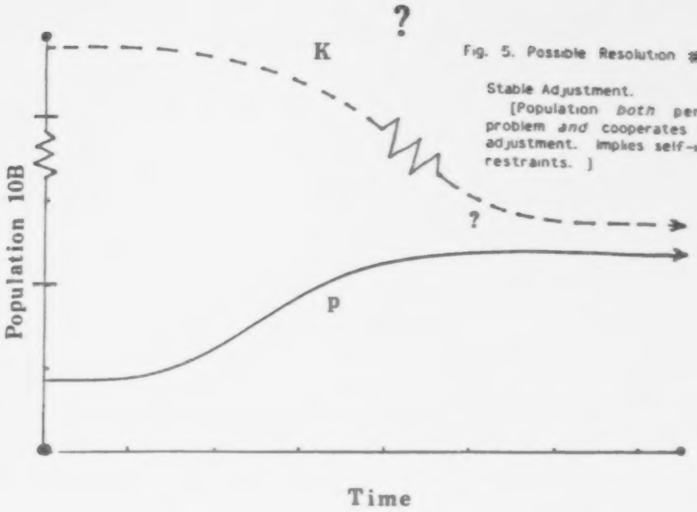

Fig. 5. Possible Resolution #1

Stable Adjustment.
[Population *both* perceives problem *and* cooperates to achieve adjustment. Implies self-imposed restraints.]

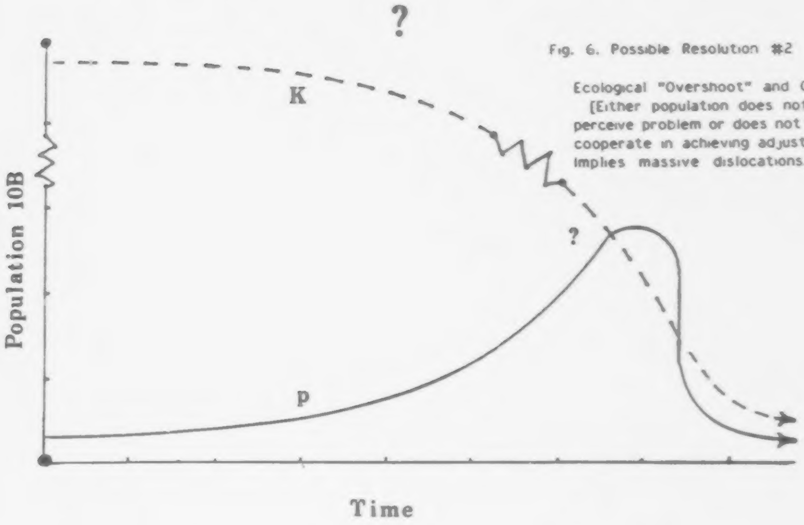

Fig. 6. Possible Resolution #2

Ecological "Overshoot" and Collapse.
[Either population does not perceive problem or does not cooperate in achieving adjustment. Implies massive dislocations.]

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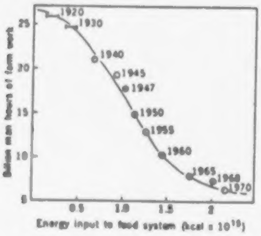
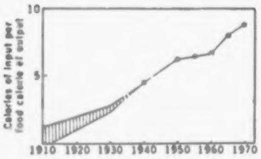
Fig. 7.
[The relative amount of Labor input to American agriculture has declined remarkably.]



Labor use on farms as a function of energy use in the food system.

Fig. 8
[But the total energy subsidy needed in the entire food system to produce one calorie of food has increased substantially. Thus, while labor efficient, the American food system is energy inefficient. This will need to change in a post-fossil fuel age.]



Energy subsidy to the food system needed to obtain 1 food calorie.

Source: Steinhart
& Steinhart, 1974

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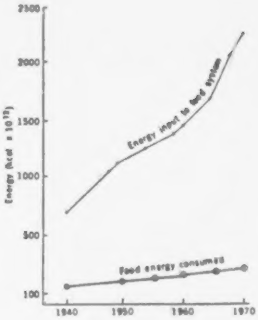
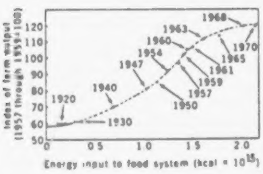


Energy use in the food system, 1940 through 1970, compared to the caloric content of food consumed.

Fig. 9
[Most of the energy absorbed in the food system has not been reflected in a corresponding output of food.]



Farm output as a function of energy input to the U.S. food system, 1920 through 1970.

Fig. 10
[Over time, there appears to be a pattern of diminishing returns in the relation of the amount of energy put into the food system and the amount of output obtained from it. The pattern suggests that future increases in output are likely to be energy-expensive, and financially even more so, as the price of oil increases.]

Source: Steinhart
& Steinhart, 1974

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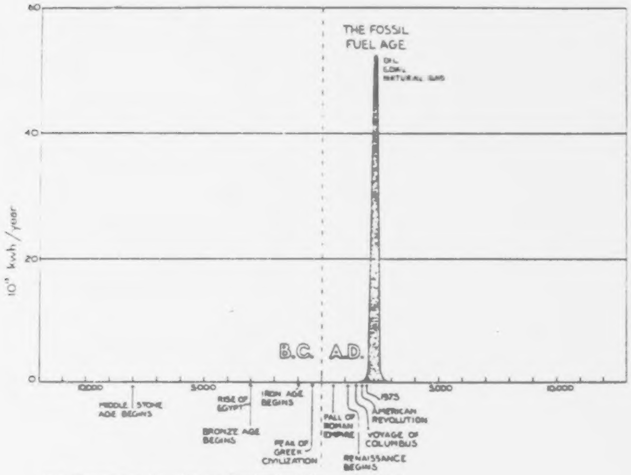
Fig. 11. The Transition Period

Mankind can use what fossil fuels remain to engineer a transition to a sustainable, solar base, or it can fail to do so -- and in failing, hasten and heighten the drama of its own extinction.



The Fossil Fuel Age in the Context of Human History.

Transition report. 1975. Office of Energy Research and Planning, Governor's Office, State of Oregon (after M. King Hubbert)

Our inability to perceive the problem at hand will not alter the nature of the fundamental problem itself. Ignoring the problem will not make it go away. Indeed it is more likely to heighten the energy-intensive conflicts involved in fighting over the remaining diminished supplies. There is open talk of potential warfare in the Middle East to preserve access to "our" oil, now so crucial for American forms of agriculture.

There is considerable irony and perhaps massive tragedy implied in the evolution of our global agricultural system towards greater and greater dependence upon fossil fuels at a time when their supply is known to be declining. Agriculture should by definition be solar-sustainable, for its very essence is to capture and fix radiant solar energy in chemically bonded forms. Yet in the name of "development" we now seem intent upon transforming the few remaining solar agricultural systems towards an irreversible dependence upon fossil fuel subsidies.

A *true* call for an end to "subsidized agriculture" would radically transform and permanently replace contemporary energy-subsidized agribusiness with small-scale, solar-efficient systems of agriculture throughout the world. Thus, it is clear that the real lesson to be learned from the continuing collapse of Third World agricultural systems is that the demise of Western agriculture is not far off if we persist in ignoring fundamental ecological constraints upon agroecosystems as we have done so dramatically in Third World areas. If we fail to learn this lesson — and quickly — we are likely to perpetuate and accentuate the world's agricultural conflicts in the years to come.

II

100TH CONGRESS
2D SESSION

S. 2666

Entitled the "Global Environmental Protection Act of 1988".

IN THE SENATE OF THE UNITED STATES

JULY 28, 1988

Mr. STAFFORD (for himself, Mr. BAUCUS, Mr. CHAFEE, Mr. DURENBERGER, and Mr. GORE) introduced the following bill; which was read twice and referred to the Committee on Environment and Public Works

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A BILL

Entitled the "Global Environmental Protection Act of 1988".

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "Global Environmental Protection Act of 1988".

SEC. 2. FINDINGS.

The Congress, recognizing the profound, irreversible and potentially catastrophic impacts of humanity's activities on the global atmosphere and the world's environment, and the inability of science to predict with certainty the consequences for humanity of any such changes, hereby declares that each person has a responsibility and obligation to avoid contamination of the atmosphere.

TITLE I—ELIMINATION AND REGULATION OF GLOBAL CHANGE POLLUTANTS

PART A—CHLOROFLUOROCARBONS AND RELATED CHEMICALS

SECTION 101. SHORT TITLE.

This part may be cited as the "Act to Eliminate Chlorofluorocarbons and Related Chemicals".

SEC. 102. FINDINGS.

The Congress finds that—

(1) the best available scientific evidence shows that manufactured substances, including chlorofluorocarbons, are polluting the atmosphere and destroying stratospheric ozone, as well as contributing to global climate change, and other atmospheric modifications;

(2) no level of stratospheric ozone depletion or global climate change caused by human activities can be deemed safe;

(3) stratospheric ozone depletion will lead to increased incidence of solar ultraviolet radiation at the surface of the Earth;

(4) increased incidence of solar ultraviolet radiation will cause increased rates of disease in humans

(including skin cancer), threaten food crops, and otherwise damage the natural environment;

(5) stratospheric ozone depletion and global climate change from continued emissions of chlorofluorocarbons and other halogenated carbons with ozone depleting potential, and emissions of other gases, imperil human health and the environment worldwide;

(6) in order to stabilize and eventually reduce concentrations of chlorine and bromine in the stratosphere, to conserve the stratospheric ozone layer (an exhaustible natural resource), and to reduce the extent of global climate change—

(A) emissions of chlorofluorocarbons and other substances covered by this Act, including halogenated carbons with ozone depleting potential, should be terminated rapidly, and

(B) it is necessary to control international trade in substances covered by this Act and products containing or made with processes that use such substances;

(7) the highest priority must be given to developing and deploying safe substitutes to replace ozone depleting substances within six years; and

(8) the United States needs to develop and deploy safe substitutes to replace ozone depleting substances

in order to demonstrate to the world its commitment to protect the stratosphere.

SEC. 103. OBJECTIVES AND NATIONAL GOAL.

(a) The objectives of this Act are to restore and maintain the chemical and physical integrity of the Earth's atmosphere and to protect human health and the global environment from all known and potential dangers due to atmospheric or climatic modification, including stratospheric ozone depletion, that is or may be related to the chlorofluorocarbons or other substances covered by this Act by—

(1) reducing significantly the production and emission into the atmosphere of pollutants caused by human activities,

(2) promoting the rapid development and deployment of alternatives to the use of the chlorofluorocarbons and other substances covered by this Act, and

(3) promoting additional scientific research on atmospheric or climatic modification, including stratospheric ozone depletion, and on the known and potential adverse effects therefrom on human health and the global environment.

(b) In order to achieve the objectives of this Act, it is the national goal to eliminate atmospheric emissions of manufactured substances with ozone depleting potential, including chlorofluorocarbons and other halogenated carbons with ozone depleting potential, and to reduce significantly emissions of other gases caused by human activities that are likely to affect adversely the global climate.

SEC. 104. DEFINITIONS.

As used in this Act:

(1) The term "Administrator" means the Administrator of the Environmental Protection Agency.

(2) The term "household appliances" means noncommercial personal effects, including air-conditioners, refrigerators, and motor vehicles.

(3) The term "import" means to land on, bring into, or introduce into, or attempt to land on, bring into, or introduce into, any place subject to the jurisdiction of the United States, whether or not such landing, bringing, or introduction constitutes an importation within the meaning of the customs laws of the United States.

(4) The term "manufactured substances" means any organic or inorganic chemical substances of a particular molecular identity, or any mixture, that has been manufactured for commercial purposes.

(5) The term "medical purposes" means medical devices and diagnostic products (A) for which no safe substitute has been developed and (B) which, after notice and opportunity for public comment, has been

approved and determined to be essential by the Commissioner of the Food and Drug Administration, in consultation with the Administrator.

(6) The term "person" means an individual, corporation (including a government corporation), partnership, firm, joint stock company, trust, association, or any other private entity, or any officer, employee, agent, department, or instrumentality of the Federal Government, of any State or political subdivision thereof (including any interstate body), or of any foreign government (including any international instrumentality).

(7) The term "substances covered by this Act" means those substances which are known or may reasonably be anticipated to cause or contribute to atmospheric or climatic modification, including stratospheric ozone depletion, and are listed under subsections (a) or (b) of section 105.

SEC. 105. LISTING OF REGULATED SUBSTANCES.

(a) SUBSTANCES TO BE PHASED-OUT.—Within sixty days after enactment of this Act, the Administrator shall publish a priority list of manufactured substances which are known or may reasonably be anticipated to cause or contribute to atmospheric or climatic modification, including stratospheric ozone depletion. The initial list shall include chlorofluorocarbon-11, chlorofluorocarbon-12, chlorofluorocarbon-113, halon-1211, and halon-1301.

(b) OTHER REGULATED SUBSTANCES.—Simultaneously with publication of the priority list, the Administrator shall create a list of other manufactured substances which, in the judgment of the Administrator, meet the criteria set forth in the first sentence of subsection (a). The list of other substances shall be subject to the limitations on ozone depletion potential under section 109 of this Act and shall include chlorofluorocarbon-22, chlorofluorocarbon-114, chlorofluorocarbon-115, carbon tetrachloride, methyl chloroform, and methylene chloride. At least annually thereafter, the Administrator shall publish a proposal to add to such list each other manufactured substance which, in the judgment of the Administrator, meets the criteria set forth in the first sentence of subsection (a). Within one hundred and eighty days of any such proposal, after allowing an opportunity for public comment, the Administrator shall promulgate a regulation adding each such substance to the list, unless the Administrator determines that such substance clearly does not meet the criteria set forth in the first sentence of subsection (a).

(c) OZONE DEPLETION FACTOR.—Simultaneously with publication of the lists or additions thereto under this section, and at least annually thereafter, the Administrator shall assign to each listed substance a numerical value representing the ozone depletion potential of such substance, on a mass (per kilogram) basis, as compared with chlorofluorocarbon-11. The numerical value shall, for the purposes of section 109, constitute the ozone depletion factor of each such substance. Until the Administrator promulgates regulations under this subsection, the following ozone depletion factors shall apply:

SUBSTANCE	OZONE DEPLETING FACTOR
Chlorofluorocarbon-11	1.0
Chlorofluorocarbon-12	1.0
Chlorofluorocarbon-22	0.05
Chlorofluorocarbon-113	0.78
Carbon tetrachloride	1.06
Methyl chloroform	0.10
Halon-1211	2.69
Halon-1301	11.43

SEC. 106. REPORTING REQUIREMENTS.

(a) PRIORITY LIST.—Within ninety days after enactment of this Act, each person producing a substance listed pursuant to subsection (a) of section 105 shall file a report with the Administrator setting forth the amount of the substance that was produced by such person during calendar year 1986. Not less than annually thereafter, each producer shall file a report with the Administrator setting forth the production levels of such substance in each successive twelve-month period until such producer ceases production of the substance. Each such report shall be signed and attested by a responsible corporate officer.

(b) OTHER REGULATED SUBSTANCES.—Within ninety days of the date on which a substance is placed on the list under subsection (b) of section 105, each person shall file a report with the Administrator setting forth the amount of the substance that was produced by such person during the twelve months preceding the date of listing. Not less than annually thereafter, each producer shall file a report with the Administrator setting forth the production levels of such substance in each successive twelve-month period until such producer ceases production of the substance. Each such report shall be signed and attested by a responsible corporate officer.

SEC. 107. PRODUCTION PHASEOUT.

(a) Effective January 1, 1989, it shall be unlawful for any person to produce a substance listed pursuant to subsection (a) of section 105 in annual quantities greater than that produced by such person during calendar year 1986.

(b) Effective January 1, 1990, it shall be unlawful for any person to produce a substance listed pursuant to subsection (a) of section 105 in annual quantities greater than 75 per centum of that produced by such person during calendar year 1986.

(c) Effective January 1, 1991, it shall be unlawful for any person to produce a substance listed pursuant to subsection (a) of section 105 in annual quantities greater than 50 per centum of that produced by such person during calendar year 1986.

(d) Effective January 1, 1993, it shall be unlawful for any person to produce a substance listed pursuant to subsection (a) of section 105 in annual quantities greater than 5 per centum of that produced by such person during calendar year 1986.

(e) Effective January 1, 1995, it shall be unlawful for any person to produce or release a substance listed pursuant to subsection (a) for any use other than medical purposes.

(f) Effective January 1, 1999, it shall be unlawful for any person to produce or release a substance listed pursuant to section 105 for any use other than medical purposes.

SEC. 108. LIMITATION ON USE.

(a) Effective January 1, 1994, it shall be unlawful to introduce into interstate commerce or to use a substance listed under subsection (a) of section 105 except for medical purposes approved by the Commissioner of the Food and Drug Administration, in consultation with the Administrator, and, for a period not to exceed ten years after January 1, 1994, to maintain and service household appliances.

(b) Effective January 1, 1999, it shall be unlawful to introduce into interstate commerce or to use a substance listed under subsection (b) of section 105 except for medical purposes approved by the Commissioner of the Food and Drug Administration, in consultation with the Administrator, and, for a period not to extend beyond January 1, 2004, to maintain and service household appliances. For purposes of this subsection and subsection 107(f), a manufacturing process utilizing such a substance solely as an intermediate in a manufacturing process in which the substance is wholly consumed and none is released, does not constitute a use.

SEC. 109. LIMITATION ON OZONE DEPLETION POTENTIAL.

(a) Effective January 1, 1989, it shall be unlawful for any person to produce substances covered by this Act in annual quantities that, based upon the ozone depletion factor assigned to each such substance under subsection (c) of section 105, yield a total ozone depletion potential greater than that produced by such person during calendar year 1986.

(b) Effective January 1, 1990, it shall be unlawful for any person to produce substances covered by this Act in annual quantities that, based upon the ozone depletion factor assigned to each such substance under subsection (c) of section 105, yield a total ozone depletion potential greater than 75 per centum of that produced by such person during calendar year 1986.

(c) Effective January 1, 1991, it shall be unlawful for any person to produce substances covered by this Act in annual quantities that, based upon the ozone depletion factor assigned to each such substance under subsection (c) of section 105, yield a total ozone depletion potential greater than

50 per centum of that produced by such person during calendar year 1986.

(d) Effective January 1, 1995, it shall be unlawful for any person to produce a substance listed pursuant to section 105(a) for any use other than medical purposes.

(e) The Administrator shall promulgate regulations, after notice and opportunity for public comment, which require each producer to reduce its production of—

(1) a substance listed under subsection (a) of section 105 more rapidly than the schedule provided under this Act; or

(2) a substance listed under subsection (b) of section 105 on a specific schedule not otherwise provided for in this Act.

if the Administrator determines that such revised or specific schedule (A) based on new information regarding the harmful effects on the stratosphere or climate which may be associated with a listed substance, is necessary to protect human health and the environment or (B) based on the availability of substitutes for a listed substance, is attainable. Any person may petition the Administrator to issue such regulations. The Administrator shall issue such regulations within one hundred and eighty days after receipt of any such petition, unless the Administrator denies the petition.

SEC. 110. PRODUCTION PHASE-OUT EXCEPTION FOR NATIONAL SECURITY.

(a) The President may issue such orders regarding production and use of halon-1211 and halon-1301 at any specified site or facility as may be necessary to protect the national security interests of the United States if the President personally finds that adequate substitutes are not available and that the production and use of such substance is necessary to protect such national security interests. Such orders may include, where necessary to protect such interests, an exemption from any requirement contained in this Act. The President shall notify the Congress within thirty days of the issuance of an order under this paragraph providing for any such exemption. Such notification shall include a statement of the reasons for the granting of the exemption. An exemption under this paragraph shall be for a specified period which may not exceed one year. Additional exemptions may be granted, each upon the President's issuance of a new order under this paragraph. Each such additional exemption shall be for a specified period which may not exceed one year. No exemption shall be granted under this paragraph due to lack of appropriation unless the President shall have specifically requested such appropriation as a part of the budgetary process and the Congress shall have failed to make available such requested appropriation.

SEC. 111. CERTIFICATION OF EQUIVALENT PROGRAMS.

(a) IMPORTS.—Effective twelve months after the date on which a substance is placed on the priority list pursuant to section 105, it shall be unlawful for any person to import such substance, any product containing such substance, or any product manufactured with a process that uses such substance unless the Administrator, in consultation with the Secretary of State (the Secretary), has published a decision, after notice and opportunity for public comment, certifying that the nations in which such substance or product was manufactured and from which such substance or product is imported have established and are fully implementing programs that require reduced production of such listed substance, and limit production of other substances covered by this Act, on a schedule and in a manner that is at least as stringent as the reduction schedule for, and limitations on, domestic production which apply under this Act. The prohibition on the import of any product manufactured with a process that uses a substance listed under subsection (a) of section 105 shall include, after notice and opportunity for public comment, any product which the Administrator has reason to believe may have been manufactured with a process that uses such substance. The Administrator's decision that a product may have been manufactured with a process that uses such substance shall constitute a rebuttable presumption.

(b) Certification of National Program.—The Administrator shall not certify any national program under subsection (a) unless it is determined that—

(1) the Nation has adopted legislation or regulations which give the reduction schedule for each listed substance the force of law; and

(2) the legislation or regulations include reporting requirements and enforcement provisions no less stringent than those specified in this Act, and that the information contained in such reports is available to the Administrator and the Secretary.

(c) Revocation.—At least annually, the Administrator, in consultation with the Secretary, shall review each certification made under this section and shall revoke such certification, after notice and opportunity for public comment, unless it is determined that the conditions of subsections (a) and (b) remain satisfied and that the reduction schedule for each listed substance is in fact being carried out in such nations. Any such revocation shall take effect one hundred and eighty days after notice of the revocation has been published.

(d) Allocation.—Any person who imports a substance covered by this Act or a product containing such substance shall, for the purposes of section 107 (production phaseout for priority list) and section 109 (limitation on ozone depletion potential), shall be deemed to have produced an equivalent amount of such substance on the date of such importation.

SEC. 112. LABELING.

(a) Effective ninety days after the date on which a substance is placed on a list maintained under subsection (a) or (b) of section 105, no container in which such substance is stored or transported, no product containing such substance, and no product manufactured with a process that uses a listed substance shall be introduced into interstate commerce unless it bears a label stating either of the following, as appropriate—

(1) Contains (insert name of listed substance) a substance which harms public health and environment by destroying ozone in the upper atmosphere and by disrupting the climate.

(2) Manufactured with (insert name of listed substance), a substance which harms public health and environment by destroying ozone in the upper atmosphere and by disrupting the climate.

The Administrator shall issue regulations to implement the labeling requirements of this section within six months after enactment of this section, after notice and opportunity for public comment. Such regulations shall require all containers and products which are subject to this section and introduced or reintroduced into commerce later than ninety days after promulgation of such regulations to bear the appropriate label. Unless and until such regulations have been promulgated and become effective, the required label shall be permanently affixed on the face of such product, with the lettering and background in contrasting colors and the letters themselves not less than two inches in height (or 20 per centum of the height of the product which is less than four inches in height). Neither the labeling requirement nor any other provision of the Global Environmental Protection Act of 1988, including the Act as a whole, shall constitute, in whole or part, a defense to liability or a cause for reduction in damages in any suit, whether civil or criminal, brought under any law, whether Federal or State, other than a suit for failure to comply with the labeling requirements of this section.

SEC. 113. MANUFACTURE AND DISPOSAL.

(a) Effective January 1, 1990—

(1) A substance listed pursuant to this Act shall be deemed to meet the requirements of section 3001 of the Resource Conservation and Recovery Act.

(2) A substance listed pursuant to this Act shall be disposed of only through incineration or other means which assures 99.999 per centum destruction of such substance.

(3) Any appliance, machine or other good containing a listed substance in bulk (including but not limited

to refrigerators and air-conditioners) shall be accepted for disposal only by persons licensed to accept such goods and shall be disposed of only after such substance has been removed from confinement and destroyed pursuant to the requirements of this Act. Unless and until regulations establishing a program for approving, licensing, and assuring the financial responsibility of persons to accept goods containing such substances, only governmental entities, or their agents, contractors or employees, are authorized to do so.

(4) No listed substance shall be vented into the atmosphere or otherwise released in a fashion which permits it to enter the environment in other than de minimus quantities.

(5) Any product in which a listed substance has been incorporated so as to constitute an inherent element of such product, including but not limited to rigid and soft foams, shall be disposed of only through incineration or other means which result in not less than 99.999 per centum destruction.

(b) Effective July 1, 1990—

(1) No person shall manufacture, process, distribute in commerce or otherwise use (except for medical purposes) any listed substance in any manner other than a totally enclosed manner. "Totally enclosed"

means that during the lifetime of the good in question not more than 5 per centum of the original charge or volume of such substance will be released during the course of ordinary and customary use of such good, including repairs or disposal.

(2) No person shall manufacture, process, distribute in commerce or otherwise use (except for medical purposes) a listed substance in a totally enclosed manner without—

(A) installing on such device a servicing aperture which will allow service and repair of such good with release of only de minimus amounts of such substance,

(B) assuring the availability and actual use of servicing equipment adequate to assure the achievement of no more than a de minimus release of such substance.

(c) For purposes of this section a "de minimus" amount is 0.050 per centum of the total charge of such substance or five pounds, whichever is less, released during a period of twelve months.

PART B—CARBON DIOXIDE

SEC. 114. SHORT TITLE.

This part may be cited as the "Act to Reduce and Stabilize Atmospheric Concentrations of Carbon Dioxide".

SEC. 115. FINDINGS.

The Congress finds that—

(1) there is widespread agreement, and no credible scientific dispute, that increases in atmospheric concentrations of carbon dioxide will increase the temperature of the planet;

(2) current emissions of carbon dioxide are approximately seventy times as great as those a century ago;

(3) average concentrations of carbon dioxide in the absence of major contributions from human activity have ranged between one hundred and eighty and two hundred and eighty parts per million;

(4) the current concentration of carbon dioxide is approximate three hundred and eighty parts per million;

(5) concentrations of carbon dioxide because of human activity are increasing at the rate of about 4 per centum per decade;

(6) there has already been an observed increase in globally averaged temperature of 0.7 degrees Centigrade during the last century;

(7) increases in North Atlantic Ocean temperatures of 0.2 to 0.3 degrees Centigrade have been measured;

(8) ocean water levels have increased;

(9) the years 1981, 1983, and 1987 are the hottest on record;

(10) to date, the year 1988 will exceed the temperatures of all previous years on record;

(11) elevated temperatures and drought are now prevailing in many of the world's agricultural areas;

(12) all of these changes are consistent with predictions that increases in carbon dioxide will lead to global temperature increases;

(13) further temperature increases of as much as 4 degrees Centigrade will be experienced by the year 2030 if concentrations of carbon dioxide and other trace gases continue to accelerate at current rates;

(14) even with stringent and immediate controls, global average temperatures are predicted to increase 1.0 to 2.5 degrees Centigrade;

(15) scientists are unable to state with certainty whether the global environment will respond predictably to further temperature increases, especially if they occur in combination with other alterations in the atmosphere and oceans;

(16) probable consequences of further warming will include, but cannot with certainty be said to be limited to, the following:

(A) Sea level rise of between one and four feet, accompanied by widespread flooding, estuary destruction, and increased frequency of extreme storm events such as cyclones;

(B) Disappearance of many tree and plant species in areas where they now predominate;

(C) Widespread and endemic drought in many areas of the world which now supply the bulk of humanity's foods;

(17) to minimize further climate destruction and mitigate that which is already inevitable will require that atmospheric concentrations of carbon dioxide be stabilized;

(18) the level of carbon dioxide emission reductions necessary to achieve atmospheric stabilization is uncertain, but has been estimated by some to be 50 per centum or more;

(19) given the uncertainty of the response of the global environment to further temperature increases, the prudent policy is to strive to minimize carbon dioxide emissions through all possible means rather than establish an arbitrary goal;

(20) between 20 and 25 per centum of the worldwide emissions of carbon dioxide originate in the United States;

(21) technologies and practices exist which could reduce carbon dioxide emissions substantially;

(22) the adoption of these technologies and practices would increase the efficiency and competitiveness of the United States business and industrial sector, decrease the Nation's dependence on foreign supplies of fuel, protect the agricultural sector, preserve the natural environment, and simultaneously achieve reductions in other chemicals which cause acid rain, ground level ozone, and fine particle pollution; and

(23) therefore, the United States can protect the global environment directly by reducing emissions of carbon dioxide emissions and indirectly protect such environment by demonstrating the technologies and practices which can be applied elsewhere.

SEC. 116. STATIONARY SOURCE CONTROLS.

(a)(1) Not later than January 1, 1990, the Administrator of the Environmental Protection Agency shall revise the standards under section 111(b) of the Clean Air Act to require—

(A) that such standards be expressed in terms of carbon dioxide emitted per unit of electricity output;

(B) that such standards applicable to fossil fuel fired electric utility generating units provide for emissions of carbon dioxide not to exceed the following:

(i) effective January 1, 1990, six hundred and ten pounds of carbon dioxide per million British thermal units of heat output;

(ii) effective January 1, 2000, four hundred and thirty-five pounds of carbon dioxide per million British thermal units of heat output; and

(iii) effective January 1, 2010, two hundred and eighty pounds of carbon dioxide per million British thermal units of heat output.

For purposes of this section, "heat output" includes usable energy, whether electric or thermal, measured at the point of distribution to residential, commercial, or other customers.

(2) Effective January 1, 1995, each fossil fuel fired stationary source shall comply with the standards established under section 111(b) of the Clean Air Act for new sources within such class or category, in the case of each electric utility generating source, on and after the date thirty years following the completion of construction of such source and, in the case of each other source, on and after the date thirty-five years following the completion of construction of such source.

(3) To the extent that the emissions rate limits required by this section and section 111 of the Clean Air Act through increases in combustion, generation, transmission, and utilization efficiencies, such program for achieving reductions

shall constitute enforceable continuous emissions reduction measures, enforceable by the Federal Government, States other than those in which the emissions occur, and citizens under section 304 of the Clean Air Act.

SEC. 117. MOBILE SOURCE CONTROLS.

(a) The Clean Air Act is amended as follows:

(1) In section 202(a)(3)(A)(i) inserting before the period at the end of the first sentence, the following: "and, for emissions of carbon dioxide, during and after model year 1990".

(2) in section 202(a)(3)(A)(ii) inserting the following new clause:

"(III) 1990 in the case of carbon dioxide shall contain standards which require a reduction of at least 10 per centum in 1990; at least 25 per centum in 1995; at least 50 per centum in 2000; and at least 75 per centum in 2010.".

(3) inserting in section 202(b)(1)(B) the following new language immediately before the period:

"The regulations under subsection (a) applicable to emissions of carbon dioxide from light duty vehicles and engines shall provide that emissions of carbon dioxide may not exceed—

"three hundred and sixty grams of carbon dioxide per vehicle mile from light-duty vehicles and engines manufactured during and after model year 1990;

"three hundred grams per mile for light-duty vehicles and engines manufactured during and after model year 1995;

"two hundred grams per mile for light-duty vehicles and engines manufactured during and after model year 2000; and,

"one hundred grams per mile for light-duty vehicles and engines manufactured during and after model year 2010.".

SEC. 118. RESIDENTIAL CONTROLS.

(a) Not later than January 1, 1991, the Administrator shall promulgate regulations identifying the best available residential control technology available for central furnaces, air-conditioners, and hot water heaters designed and sold for installation in single-family dwellings. For purposes of this section, "best available residential control technology" means that technology which achieves in a unit which is commercially available the maximum degree of reduction of emissions of carbon dioxide, whether directly through combustion or indirectly through consumption of electrical energy. Unless and until such regulations are promulgated and become effective, the best available control technology shall be deemed to be as follows:

(1) for furnaces, that which achieves an AFUE of 0.90 for oil, an AFUE of 0.95 for gas and a COP of 2.6 for electric heat pumps;

(2) for central air-conditioners, that which achieves an Energy Efficiency Rating of not less than 15.0; and

(3) for hot water heaters, that which achieves an EF of 64 for gas and 96 for electricity.

(b) Each new single-family dwelling for which a building permit is issued on or after January 1, 1992, which is equipped with a central furnace, central air-conditioner, or hot water heater, shall be equipped only with one which meets or exceeds the emission limitation achieved by the best available residential control technology.

(c) Effective January 1, 1993, each replacement central furnace, central air-conditioner, or hot water heater installed in a single-family dwelling shall meet or exceed the emissions limit achieved by the best available residential control technology.

(d) Not later than January 1, 1990, the Secretary of the Treasury shall recommend to the Congress means of encouraging the replacement of central furnaces, air-conditioners and water heaters and otherwise minimizing the emissions of carbon dioxide and other greenhouse gases from residential units through a system of tax or other incentives.

PART C—GROUND LEVEL OZONE

SEC. 119. SHORT TITLE.

This part may be cited as the "Act to Minimize Ground Level Ozone".

SEC. 120. FINDINGS.

The Congress finds that—

(a) ground level ozone, and the pollutants which lead to its formation, contribute substantially to the following damages—

(1) increases in global average temperatures and the consequent threats to humanity and the global environment, as described in greater particularity in the findings accompanying part B;

(2) widespread and substantial damage to crops and other vegetation, including the forests of eastern North America and Europe;

(3) injury to human health, including probable long-term damage comparable to that resulting from tobacco smoking;

(4) acidification of the soils and waters of North America and Europe;

(b) concentrations of free tropospheric ozone have doubled to quadrupled in the last century;

(c) ground level ozone is formed by the reaction of volatile organic chemicals with oxides of nitrogen in the presence of sunlight;

(d) elevated temperatures and extended summer seasons likely to accompany the global temperature increases will cause increased production of ground level ozone;

(e) virtually all oxides of nitrogen and the majority of the volatile organic chemicals result from human activities;

(f) technologies and practices exist to reduce substantially emissions of oxides of nitrogen and volatile organic chemicals; and

(g) in the absence of a program to minimize emissions of volatile organic chemicals and oxides of nitrogen, emissions and concentrations of these pollutants are projected to increase.

SEC. 121. STATIONARY SOURCE CONTROLS: OXIDES OF NITROGEN.

(a)(1) Not later than January 1, 1990, the Administrator shall propose revised standards of performance pursuant to section 111 of the Clean Air Act for emissions of oxides of nitrogen (including nitrous oxide) from fossil fuel-fired steam or electricity generating units, including both electric utility and nonutility units. Not later than January 1, 1991, the Administrator shall promulgate such revised standards of performance. Such revised standards of performance shall reflect improvements in methods for the reduction of emissions of oxides of nitrogen and shall require an emissions rate equal to or less than 0.1 pound per million British thermal units of heat input or a reduction of not less than 90 per centum from an uncontrolled state unless the Administrator determines that such limits are technologically infeasible. Unless and until such revised standards are promulgated and become final, the application of selective catalytic reduction to achieve an emissions reduction of 90 per centum shall be deemed to be such standard.

(2) Not later than January 1, 1990, the Administrator shall propose standards of performance pursuant to section 111 of the Clean Air Act for emissions of oxides of nitrogen (including nitrous oxide) from large stationary diesel and turbine engines. Not later than January 1, 1991, the Administrator shall promulgate such standards of performance. Unless and until such revised standards are promulgated and become final, the application of selective catalytic reduction to achieve an emissions reduction of 90 per centum shall be deemed to be such standard.

(b) Effective January 1, 1993, each unit of a major stationary source that is a fossil fuel-fired steam generating unit shall achieve an emissions rate of oxides of nitrogen that does not exceed, on an annual average basis, 1.0 pound per million British thermal units of heat input for cyclone boilers, 0.5 pound per million British thermal units of heat input for wall-fired boilers, and 0.4 pound per million British thermal units of heat input for tangential-fired and other boilers.

SEC. 122. STATIONARY SOURCE CONTROLS: HYDROCARBONS.

(a) Not later than two years after the enactment of this subsection, the Administrator of the Environmental Protection Agency shall publish control technique guidelines consistent with section 171(6) of the Clean Air Act for the following categories of sources:

(A) wood furniture coating;

(B) autobody refinishing;

(C) metal rolling;

(D) SOCMI distillation; and

(E) SOCMI batch process.

(b) SECTION 304(a), part A of title I of the Clean Air Act, is amended by adding the following new section:

"HYDROCARBON EMISSION CONTROLS

"SEC. 130. (a) Not later than two years after the enactment of this section, the Administrator shall promulgate regulations establishing emission limitations, standards of performance, or standards for product composition or application for hydrocarbon emissions associated with the following categories of sources—

"(1) commercial solvents;

"(2) consumer solvents;

"(3) architectural coatings;

"(4) pesticide application;

"(5) traffic marking coatings; and

"(6) metal parts coatings in military specification applications and aerospace industry applications.

"(b) With respect to existing sources or activities not subject to section 111 or section 173, the regulations under this section shall require the degree of emission reduction or control, at a minimum, achievable through the adoption of reasonably available control technology, as defined in section 171(6). In developing regulations under subsection (a)(1) and (a)(3) of this section, the Administrator shall consult with the affected industry, including the industries procuring such parts, and with representatives of the Department of Defense, the Federal Aviation Administration, and the National Aeronautics and Space Administration involved in the establishment of specifications for such parts or coatings.

"(c) For the purposes of this Act, any requirement of a regulation promulgated under this section shall be deemed a requirement of an applicable implementation plan.".

(b) Section 116 of the Clean Air Act is amended by striking "111 or 112" and inserting in lieu thereof "111, 112, or 130".

(c) Effective January 1, 1995, each major stationary source of hydrocarbons shall comply with the standards established under section 111(b) of the Clean Air Act for new sources within such class or category, on and after the date thirty-five years following the completion of construction of such source.

SEC. 123. MOBILE SOURCE CONTROLS.

VEHICLE EMISSION STANDARDS

SEC. 301. (a) Section 202(b)(1)(A) of the Clean Air Act is amended by adding at the end thereof the following new sentence: "The regulations under subsection (a) applicable to emission of hydrocarbons from light-duty vehicles and engines manufactured during and after model year 1992 shall contain standards which provide that such emissions may not exceed 0.25 gram per vehicle mile.".

(b) Section 202(b)(1)(B) of the Clean Air Act is amended by adding at the end thereof the following new sentence: "The regulations under subsection (a) applicable to emissions of oxides of nitrogen from light-duty vehicles and engines manufactured during and after model year 1990 shall contain standards which provide that such emissions may not exceed 0.4 gram per vehicle mile.".

(c) Section 202(b)(1) of the Clean Air Act is amended by adding the following new paragraph:

"(D) The Administrator shall promulgate regulations under subsection (a) applicable to emissions of particulates from light-duty vehicles and engines manufactured during and after model year 1990, and such regulations shall contain standards which provide that such emissions, may not exceed 0.08 gram per vehicle mile.".

(d) Section 202(a)(3) of the Clean Air Act is amended by inserting after subparagraph (E) the following new subparagraphs and redesignating succeeding subparagraphs accordingly:

"(F) Regulations under paragraph (1) applicable to emissions of oxides of nitrogen from heavy-duty vehicles and engines shall contain standards that provide that such emissions shall not exceed 4.0 grams per brake horsepower-hour for vehicles manufactured during and after model year 1991 and that such emissions shall not exceed 1.7 grams per brake horsepower-hour for vehicles manufactured during and after model year 1995. Regulations applicable to emissions of particulates from heavy-duty diesel vehicles and engines shall require that such emissions may not exceed 0.1 gram per brake horsepower-hour, beginning in model year 1991 with respect to buses, and in model year 1994 with respect to other heavy-duty diesel vehicles and engines.

"(G) Regulations under paragraph (1) applicable to emissions from light-duty trucks and engines manufactured during and after model year 1990 shall contain standards that provide that such emissions may not exceed 0.5 gram per vehicle mile of oxides of nitrogen, 0.5 gram per vehicle mile of hydrocarbons, 0.08 gram per vehicle mile of particulates, and 5.0 grams per vehicle mile of carbon monoxide. Such regulations shall require that light-duty trucks and engines manufactured during and after model year 1990 comply with the standard for emissions of carbon monoxide regardless of the altitude at which they are sold. For the purposes of this subparagraph, the terms 'light-duty truck' and 'light-duty truck and engine' means any motor vehicle (including the engine thereof) with a gross vehicle weight (as determined under regulations promulgated by the Administrator) of eight thousand five hundred pounds or less and a curb weight of six thousand pounds or less (as determined under regulations promulgated by the Administrator) and which—

"(i) is designed primarily for purposes of transportation of property or is a derivation of such a vehicle,

"(ii) is designated primarily for transportation of persons and has a capacity of more than twelve persons, or

"(iii) has special features enabling off-street or off-highway operation and use.

For the purposes of this section, any motor vehicle with a gross vehicle weight of six thousand pounds or less shall be a light-duty vehicle.".

(e) Section 202(a)(3)(H) of the Clean Air Act (as redesignated by this Act) is amended by adding the following new sentence: "Regulations under this section applicable to exhaust and evaporative emissions from motorcycles and motorcycle engines manufactured during and after model year 1992 shall contain standards that provide that such emissions, in the case of motorcycle engines with a displacement of less than seven hundred cubic centimeters, may not exceed 2.0 grams per vehicle mile of hydrocarbons, 17.6 grams per vehicle mile of carbon monoxide, and 2.0 grams per test of evaporative emissions, and in the case of motorcycle engines with a displacement of seven hundred cubic centimeters or more, may not exceed 3.6 grams per vehicle mile of hydrocarbons, 17.6 grams per vehicle mile of carbon monoxide, and 4.0 grams per test of evaporate emissions.".

(f) Section 202(a)(6) of the Clean Air Act is amended to read as follows:

"(6) Regulations under this section applicable to vehicles manufactured during and after model year 1991 shall require the use of onboard hydrocarbon control technology to recover emissions from the fueling of such vehicles. Such onboard hydrocarbon control technology shall be designed to accommodate all available fuels.".

(g) Section 209(b)(1) of the Clean Air Act is amended by striking ", in the aggregate,".

(h)(1) Section 202(b)(1) of the Clean Air Act is further amended by adding the following new paragraph:

"(E) The Administrator shall promulgate regulations under subsection (a) applicable to emissions of formaldehyde from light-duty vehicles and engines manufactured during and after model year 1990 which may be fueled, in whole or in part, by fuels other than gasoline. In no event may such regulations permit emissions of formaldehyde at a higher rate than from comparable gasoline-fueled vehicles.".

(2) Section 202(a)(3) of the Clean Air Act is further amended by adding at the end thereof the following new subparagraph:

"(I) The Administrator shall promulgate regulations under subsection (1) applicable to emissions of formaldehyde (i) from heavy-duty vehicles and engines and (ii) from light-duty trucks and engines manufactured during and after model year 1991 which may be fueled, in whole or in part, by fuels other than gasoline. In no event may such regulations permit emissions of formaldehyde at a higher rate than from comparable gasoline-fueled vehicles.".

(i) Section 202 of the Clean Air Act is amended by adding the following new subsection:

"(g) The Administrator shall promulgate regulations applicable to motor vehicle and other engines manufactured during and after model year 1991 that prohibit the manufacture, sale, or introduction into commerce of any engine that requires leaded gasoline.".

(j) Section 202(a) of the Clean Air Act is amended by adding the following new paragraph:

"(7)(A) To augment existing regulations controlling carbon monoxide emissions under temperatures between 68 and 86 degrees Fahrenheit, the Administrator shall prescribe regulations under paragraph (1) of this subsection applicable to emissions of carbon monoxide over a temperature range of 20 to 68 degrees Fahrenheit from light-duty vehicles and light-duty trucks manufactured during and after model year 1990.

"(B) Regulations under subparagraph (A) shall require a reduction of at least 90 per centum from the average emissions from light-duty gasoline-fueled vehicles and trucks manufactured in model year 1970 to a level not to exceed 6.2 grams per vehicle mile of carbon monoxide at 20 degrees Fahrenheit. Demonstration of compliance shall be determined under regulations promulgated by the Administrator and may be based on testing of randomly selected engine families.".

ASSURANCE OF IN-USE COMPLIANCE

SEC. 302. (a)(1) Section 202(d)(1) of the Clean Air Act is amended by striking "five years or of fifty thousand miles" and inserting in lieu thereof "ten years or of one hundred thousand miles".

(2) The amendment made by this subsection shall take effect with respect to light-duty vehicles and engines manufactured during and after model year 1990.

(b) Section 202 of the Clean Air Act is amended by adding the following new subsection:

"(h) Each emission standard under this section shall apply to and be met by each and every vehicle or engine sold, offered for sale, introduced into commerce, or imported, and may not be met or complied with by the average of the performance of various vehicles, engines, engine families, or models manufactured by the same manufacturer.".

(c) Section 206(a) of the Clean Air Act is amended by adding the following new paragraph:

"(4) Not later than one year after the enactment of this paragraph, the Administrator shall promulgate regulations adding an idle test mode to the Federal Test Procedure for light-duty vehicles as in effect on such date of enactment. Such modified test procedure shall be used for the certification of light-duty vehicles and engines manufactured during or after model year 1990.".

(d) Section 206(b)(2)(A) of the Clean Air Act is amended by adding the following new clause:

"(iii) A certificate of conformity shall be suspended or revoked under clause (i) with respect to a class or subclass of vehicles if that class or subclass fails a sampling plan having an acceptance quality level of 10 per centum.".

(e)(1) Section 207(c)(1) of the Clean Air Act is amended by striking the word "properly" each time it occurs and inserting in lieu thereof "normally".

(2) Section 207(c) of the Clean Air Act is amended by adding the following new paragraphs:

"(4) In making determinations of nonconformity under this subsection, the Administrator shall take into account information collected under any State vehicle emission control inspection and maintenance program. Any State in which such a program is operating may petition the Administrator to make a determination of nonconformity under paragraph (1) on the basis of information collected in such program. The Administrator shall act upon such petition within sixty days of receipt of such petition.

"(5) For the purpose of paragraph (1), the phrase 'normally maintained and used' means the maintenance and use ordinarily to be expected in the hands of the ultimate purchasers, not necessarily in accordance with instructions under paragraph (3), but not including intentional misfueling or intentional violations of section 203(a)(3).".

(3) Section 207(c) of the Clean Air Act is further amended by adding the following new paragraph at the end thereof:

"(6) Not later than one hundred and eighty days after enactment of the Clean Air Standards Attainment Act of

1987, the Administrator shall establish at least one testing center in addition to the existing two testing centers, which shall be located at a site that represents high altitude conditions, to ascertain whether, when in actual use throughout their useful life (as determined under section 202(d)), each class or category of vehicle and engine to which regulations under section 202 apply conforms to the emission standards of such regulations. The Administrator shall, in cooperation with the States, conduct routine testing of a representative sample of classes or categories of vehicles and engines to which regulations under section 202 apply. In carrying out such tests, the Administrator shall assure that the testing procedures and methods are of sufficient accuracy and consistency to carry out the purposes of this section. For the purposes of this paragraph, the term 'high altitude conditions' refers to high altitude as defined in Environmental Protection Agency regulations in effect as of the enactment of this Act.".

(f)(1) Section 203(a)(3) of the Clean Air Act is amended to read as follows:

"(3)(A) for any person to remove or render inoperative any device or element of design installed on or in a motor vehicle or motor vehicle engine in compliance with regulations under this title prior to its sale and delivery to the ultimate purchaser, or for any person knowingly to remove or render inoperative any such device or element of design after such sale and delivery to the ultimate purchaser, except as may be temporarily necessary in the course of routine proper maintenance; or

"(B) for any person to manufacture or sell, or offer to sell, any part or component intended for use with, or as part of, any motor vehicle or motor vehicle engine, where a principal use of such part or component is to bypass, defeat, or render inoperative any device or element of design installed on or in a motor vehicle or motor vehicle engine in compliance with regulations under this title, and where such part or component is being offered for sale for such use or put to such use within the specific knowledge of such person; or".

(2) Section 205 of the Clean Air Act is amended to read as follows:

"SEC. 205. (a) Any person who violates paragraph (1), (2), or (4) of section 203(a) or any manufacturer or dealer who violates paragraph (3)(A) of section 203(a) shall be subject to a civil penalty of not more than $10,000. Any other person who violates paragraph (3)(A) of section 203(a) or any person who violates paragraph (3)(B) of section 203(a) shall be subject to a civil penalty of not more than $2,500. Any such violation with respect to paragraph (1), (3), or (4) of section 203(a) shall constitute a separate offense with respect to each motor vehicle or motor vehicle engine.

"(b) A civil penalty for a violation of section 203 shall be assessed by the Administrator by an order made on the record after opportunity for a hearing. In connection with any proceeding under this section the presiding officer may issue subpoenas for the attendance and testimony of witnesses and the production of papers, books, and documents.

"(c) In determining the amount of a civil penalty, the Administrator shall take into account the gravity of the violation, the size of the violator's business, the violator's history of compliance, action taken to remedy the violation, and the effect of the penalty on the violator's ability to continue in business.

"(d) If any person fails to pay a civil penalty assessed under this section—

"(1) after the order making the assessment has become a final order and if such person does not file a petition for judicial review of the order in accordance with section 307, or

"(2) after a court in any action brought for judicial review has entered a final judgment in favor of the Administrator or the action has otherwise been terminated if such person has filed a petition for review under section 307,

the Attorney General shall recover the amount assessed (plus interest from the date of the expiration of sixty days from the date of the order, or from the date of such final judgment, as the case may be) in an action brought in any appropriate district court for the United States. In such an action, the validity, amount, and appropriateness of such penalty shall not be subject to review.".

(3) Section 203(c) of the Clean Air Act is amended by striking "from section 203(a)(3)" the second time it appears.

(g)(1)(A) Section 207(a)(3) of the Clean Air Act is amended by striking the last sentence and inserting in lieu thereof the following: "The term 'designed for emission control' as used in the preceding sentence means a catalytic converter, thermal reactor, trap oxidizer, oxygen sensor, air pump, air flow sensor, electronic control unit and other elements of a fuel metering system, exhaust gas recirculation system, evaporative emission control system, and altitude compensation system, or any other component that is first installed on or in a vehicle in mass production after the date of enactment of the Clean Air Standards Attainment Act of 1987 and that is installed for the primary purpose of reducing vehicle emissions. Such term shall not include those vehicle components which were in general use prior to model year 1968.".

(B) The penultimate sentence of section 207(b)(2) of the Clean Air Act is amended by striking all after "catalytic converter, thermal reactor," and inserting in lieu thereof "trap oxidizer, oxygen sensor, air pump, air flow sensor, electronic control unit and other elements of a fuel metering system, exhaust gas recirculation system, evaporative emission control system, and altitude compensation system, or any other component that is first installed on or in a vehicle in mass production after the date of enactment of the Clean Air Standards Attainment Act of 1987 and that is installed for the primary purpose of reducing vehicle emissions.".

(2) Section 207(c) of the Clean Air Act is further amended by adding at the end thereof the following new paragraph:

"(7) The Administrator shall promulgate regulations requiring each State which is required to implement a vehicle inspection and maintenance program to adopt quality control audits to assure that such inspections detect and report to the Administrator any patterns of defects in any manufacturer's emission control systems. The Administrator shall annually report to the Congress, with respect to each manufacturer, any significant finding of repeated or common emission system defects and the actions taken to remedy such nonconformity through ordered or voluntary recalls or other actions authorized by this Act.".

(3)(A) Section 207(c)(3)(B) of the Clean Air Act is amended by striking all after "no commercial relationship" and inserting in lieu thereof a period.

(B) Section 203(a)(4)(C) of the Clean Air Act is amended by striking "except as provided in subsection (c)(3) of section 207,".

(C) Section 203(a) of the Clean Air Act is amended by adding at the end thereof the following: "Paragraph (4)(C) shall not apply to the provision of any communication regarding any part, component, or system, or service provided without charge under the terms of the purchase agreement.".

(4) Section 207(e) of the Clean Air Act is amended by inserting "(1)" after "(e)" and by adding the following new paragraph:

"(2)(A) Each manufacturer of a new motor vehicle shall affix, and each dealer shall maintain, on each motor vehicle manufactured during and after model year 1990, a label indicating the full cost of applying the warranty under subsections (a) and (b) to such new motor vehicle. The form and content of such label, and the manner in which such label shall be affixed, shall be prescribed by the Administrator by rule, except that each such label shall contain, in bold face type, the following statement: 'The vehicle manufacturer or dealer may offer to sell warranties extending beyond those required by sections 207 (a) and (b) of the Clean Air Act and covering the emission system or other components or parts of the vehicle. The purchaser of the vehicle does not have any obligation to purchase the extended warranty from the manufacturer or the dealer. The vehicle purchaser may elect to buy an extended warranty from any other vendor of such warranties.'.

"(B) The Administrator may permit a manufacturer to comply with the provisions of subparagraph (A) by permitting such manufacturer to disclose the information required under this paragraph on the label required under section 3 of the Automobile Information Disclosure Act (15 U.S.C. 1232).

"(C) A violation of subparagraph (A) shall be treated as a violation of section 3 of the Automobile Disclosure Act (15 U.S.C. 1232).

"(D) The Administrator shall utilize the authorities of section 208 of this Act to verify the costs disclosed by each manufacturer under subparagraph (A).".

(5) Section 207(g) of the Clean Air Act is amended to read as follows:

"(g) For the purposes of this section, the owner of any motor vehicle or motor vehicle engine warranted under this section is responsible in the proper maintenance of such vehicle or engine to replace and to maintain, at his expense and at any service establishment or facility of his choosing, such items as spark plugs, points, condensers, and any other part, item, or device related to emission control (but not designed for emission control under the last two sentences of subsection (a)(3)), unless such part, item, or device is covered by any warranty not required by this Act.".

REGULATION OF FUELS

SEC. 303. (a) Section 211 of the Clean Air Act is amended by adding the following new subsections:

"(h)(1) After July 1, 1990, the sale or introduction into commerce of diesel fuel for use in motor vehicles, which fuel has a sulfur content in excess of 0.05 per centum by weight, shall be prohibited.

"(2) The fuel required to be used in certification of heavy-duty diesel vehicles and engines manufactured during and after model year 1991 shall have a sulfur content that does not exceed 0.05 per centum by weight.

"(3)(A) Paragraph (1) of this subsection and any regulations promulgated by the Administrator thereunder shall not require a small refinery to reduce the sulfur content of diesel fuel to 0.05 per centum by weight prior to July 1, 1993.

"(B) For the purpose of this subsection, the term "small refinery" means a refinery—

"(i) the diesel fuel producing capacity of which was in operation or under construction at any time during the one-year period immediately preceeding October 1, 1987,

"(ii) which has a crude oil or bona fide feed stock capacity (as determined by the Administrator) of one hundred and seventy-five thousand barrels per day or less, and

"(iii) which is owned or controlled by a refiner with a total combined crude oil or bona fide feed stock capacity (as determined by the Administrator) of three hundred and fifty thousand barrels per day or less.

"(4) The Administrator shall report to the Congress not later than the date six months after the enactment of this subsection, on whether a sulfur content in diesel fuel of 0.05 per centum by weight is necessary to assure that heavy-duty diesel vehicles and engines can achieve the particulate emission standards specified in section 202(a)(3)(F) or in regulations under section 202 for model year 1991 and model year 1994, or is otherwise warranted for the protection of public health.

"(i) Not later than two years after the date of enactment of this subsection, the Administrator shall promulgate regulations under this subsection requiring that the Reid vapor pressure of gasoline sold, offered for sale, or introduced into commerce during warm weather months (as defined by the Administrator), shall not exceed nine pounds per square inch, or with respect to any region established under section 178, any lower level requested by the regional commission for such region established under section 178(b). After April 1, 1990, no manufacturer or importer of gasoline may sell, offer for sale, or introduce into commerce any fuel which does not comply with such regulations. For ethanol/gasoline blends containing 10 per centum denatured anhydrous ethanol, the Reid vapor pressure limitations promulgated pursuant to this subsection shall be 1.0 pound per square inch greater than the applicable Reid vapor pressure limitations which apply to gasoline: *Provided, however,* That a refiner, distributor, blender, marketer, reseller, carrier, retailer, or wholesale purchaser-consumer shall be deemed to be in full compliance with the provisions of this subsection and the regulations promulgated thereunder if it can demonstrate (by showing receipt of a certification or other evidence acceptable to the Administrator) that (I) the gasoline portion of the blend complies with the Reid vapor pressure limitations promulgated pursuant to this subsection, and (II) the ethanol portion of the blend does not exceed its waiver condition under subsection (f)(4).

"(j)(1) After October 1, 1989, the sale or introduction into commerce of gasoline for use in motor vehicles, in any area that is a nonattainment area as defined in section 171(2) for carbon monoxide, during the period from October 1 to

April 1 of each year, which fuel has an oxygen content less than 2 per centum oxygen by weight, shall be prohibited.

"(2) After October 1, 1990, the sale or introduction into commerce of gasoline for use in motor vehicles, in any area that is a nonattainment area as defined in section 171(2) for carbon monoxide during the period from October 1 to April 1 of each year, which fuel has an oxygen content less than 3.7 per centum oxygen by weight, shall be prohibited.

"(3) The Administrator may waive the requirements of paragraph (1) or (2) in whole or in part with respect to the level of oxygen content, the timing of available oxygenated gasoline, or the use of oxygenated fuels, in a specific area, where full implementation of such provision may reasonably be anticipated to result in an unacceptable increase in levels of other air pollutants.

"(4) Not later than two years after the enactment of this subsection, the Administrator shall submit a report to the Environment and Public Works Committee of the United States Senate and the Energy and Commerce Committee of the House of Representatives concerning the increased use of oxygenated fuels nationwide; and the use of oxygenated fuels with an oxygen content by weight greater than 3.7 per centum. Such report shall include an analysis of emissions, drivability, fuel volatility and availability of gasoline with increased oxygen levels.".

(b)(1) Section 211(d) of the Clean Air Act is amended to read as follows:

"(d)(1) Any person who violates subsection (a), (f), (h) or (j) or the regulations prescribed under subsection (c), (h), or (i) or who fails to furnish any information required by the Administrator under subsection (b) shall be subject to a civil penalty of not more than $10,000 for each and every day of such violation. Such civil penalty shall be assessed by the Administrator by an order made on the record after opportunity for a hearing. In connection with any proceeding under this section the presiding officer may issue subpoenas for the attendance and testimony of witnesses and the production of papers, books, and documents.

"(2) In determining the amount of a civil penalty, the Administration shall take into account the gravity of the violation, the size of the violator's business, the violator's history of compliance, action taken to remedy the violation, and the effect of the penalty on the violator's ability to continue in business.

"(3) If a person fails to pay a civil penalty assessed under this subsection—

"(A) after the order making the assessment has become a final order and if such person does not file a petition for judicial review of the order in accordance with section 307, or

"(B) after a court in any action brought for judicial review has entered a final judgment in favor of the Administrator or the action has otherwise been terminated if such person has filed a petition for review under section 307,

the Attorney General shall recover the amount assessed (plus interest from the date of the expiration of sixty days from the date of the order, or from the date of such final judgment, as the case may be) in an action brought in any appropriate district court for the United States. In such an action, the validity, amount, and appropriateness of such penalty shall not be subject to review.".

(2) Section 211(c) of the Clean Air Act is amended by adding a new paragraph as follows:

"(5) Regulations under this subsection shall prohibit any person from introducing, or causing or allowing the introduction, of a regulated fuel or fuel additive into a motor vehicle not designed for such fuel or fuel additive.".

(b)(1) Effective January 1, 1992 each State shall implement a vehicle emission control inspection and maintenance program.

(2) The term "vehicle emission control inspection and maintenance program" as used in section 172(d) means a program to reduce in-use emissions of hydrocarbons, carbon

monoxide, oxides of nitrogen, and diesel particulates from motor vehicles that—

(A) covers all vehicles regularly operating in the program area;

(B) includes at a minimum (i) each Metropolitan Statistical Area (as defined by the Director of the Bureau of the Census) with a population of one hundred thousand or more according to the 1985 Census, containing a nonattainment area, and (ii) each area identified under section 178(c)(1);

(C) requires annual emission testing and necessary adjustment, repair, or maintenance;

(D) requires direct inspection of components of vehicle emission control systems (including evidence of misfueling) and, where such components have been rendered inoperative, the repair or replacement of such components;

(E) requires inspection of heavy-duty vehicle exhaust or compliance with existing standards for the opacity of such exhaust;

(F) is operated on a centralized or, with respect to emission testing, computerized basis; and

(G) has a repair cost waiver in the case of failure of at least $200, or provides that any repair cost waiver limit shall apply only to costs that are not covered by a warranty under section 207.".

PART D—METHANE

SEC. 123. SHORT TITLE.

This part may be cited as the "Methane Emissions Elimination Act".

SEC. 124. METHANE SOURCE IDENTIFICATION AND ASSESSMENT.

(a) Not later than January 1, 1991, the Administrator of the Environmental Protection Agency, in consultation with the Administrators of the National Oceanic and Atmospheric Administration and the National Aeronautics and Space Administration, shall submit to the Congress a report on the following:

(1) the contribution of methane to global climate change;

(2) the sources and sinks of methane;

(3) the methods of controlling emissions of methane; and,

(4) the relationship between emissions of methane and concentrations of other trace gases, including the hydroxyl radical.

(b) The Solid Waste Disposal Act is amended by—

(1) inserting in section 4001 immediately before "are environmentally" the following: "minimize emis-

sions and other releases to the environment and which are otherwise".

(2) in section 4002(c)(1) striking the words "reasonable protection of ambient air quality" and substituting "and the minimization of emissions and other releases to the environment of pollutants including, but not limited to, methane or other harmful gases or materials."

(3) in section 4003(a) adding a new subsection (7) as follows:

"(7) The plan shall provide for methods (including prohibitions on the nature of materials which are disposed), practices, or technologies which minimize emissions of methane and other gases, both during operation and after closure."

(4) in section 4007(a) inserting immediately before the period at the end of the second sentence the following:

", provided that the Administrator determines that such plan satisfies the requirements of paragraph (7) of section 4003. Plans which fail to satisfy such requirements shall be disapproved".

(c) Not later than January 1, 1991, the Administrator shall promulgate regulations implementing the requirements of this section and requiring State plans developed under subtitle D of the Solid Waste Disposal Act to be amended and either approved or disapproved by July 1, 1992. Any plan not affirmatively approved by such date shall be deemed disapproved for purposes of the Solid Waste Disposal Act. Amended plans shall require all facilities constructed after January 1, 1993 subject to subtitle D to be designed, constructed and operated so as to minimize emissions of methane and shall require all existing facilities to be modified prior to January 1, 1993 and thereafter operated so as to minimize emissions of methane and other pollutants.

(c) Effective January 1, 1994 mass releases of methane, whether through intentional venting of wells or otherwise, and flaring of methane are prohibited.

PART E—MISCELLANEOUS PROVISIONS

SEC. 125. FEDERAL ENFORCEMENT.

(a) COMPLIANCE ORDERS.—(1) Whenever on the basis of any information the Administrator determines that any person has violated or is in violation of any requirement of this title, the Administrator may issue an order assessing a civil penalty for any past or current violation, requiring compliance immediately or within a specified time period, or both, or the Administrator may commence a civil action in the United States district court in the district in which the violation occurred for appropriate relief, including a temporary or permanent injunction.

(2) Any order issued pursuant to this subsection may include a suspension or revocation of any permit issued by the Administrator and shall state with reasonable specificity the nature of the violation. Any penalty assessed in the order shall not exceed $25,000 per day of noncompliance for each violation of a requirement of this Act. In assessing such a penalty, the Administrator shall take into account the seriousness of the violation and any good faith efforts to comply with applicable requirements.

(b) PUBLIC HEARING.—Any order issued under this section shall become final unless, no later than thirty days after the order is served, the person or persons named therein request a public hearing. Upon such request the Administrator shall promptly conduct a public hearing. In connection with any proceeding under this section the Administrator may issue subpenas for the attendance and testimony of witnesses and the production of relevant papers, books, and documents, and may promulgate rules for discovery procedures.

(c) VIOLATION OF COMPLIANCE ORDERS.—If a violator fails to take corrective action within the time specified in a compliance order, the Administrator may assess a civil penalty of not more than $25,000 for each day of continued noncompliance with the order and the Administrator may suspend or revoke any permit issued to the violator.

(d) CRIMINAL PENALTIES.—Any person who—

(1) knowingly exceeds the production limits under section 107 (production phase-out for initial list) or section 109 (limitation on ozone depletion potential);

(2) knowingly introduces into interstate commerce a substance that was produced in violation of section 107 or section 109;

(3) knowingly imports a substance listed under section 105, a product containing such substance, or a product manufactured with a process that uses such substance, in violation of section 111 (certification of equivalent programs);

(4) knowingly introduces into interstate commerce a substance or product in violation of section 108 (limitation on use) or section 112 (labeling);

(5) knowingly omits material information or makes any false material statement or representation in any application, record, report, permit, or other document filed, maintained, or used for purposes of compliance with this title; or

(6) knowingly produces, transports, distributes, or uses any substance listed under section 105, a product containing such substance, or a product manufactured with a process that uses such substance, and who knowingly destroys, alters, conceals, or fails to file any record, application, report, or other document required

to be maintained or filed for purposes of compliance with this title

shall, upon conviction, be subject to a fine in accordance with title 18 of the United States Code for each day of violation, or imprisonment not to exeed two years, or both. If conviction is for a violation committed after a first conviction of such person under this paragraph, the maximum punishment under the respective paragraph shall be doubled with respect to both fine and imprisonment.

(e) CIVIL PENALTY.—Any person who violates any requirement of this title shall be liable to the United States for a civil penalty in an amount not to exceed $25,000 for each such violation.

(f) VIOLATIONS.—Each day of violation of any requirement of this title shall, for purposes of this section, constitute a separate violation. In addition, for purposes of section 107 (production phase-out for initial list), section 108 (limitation on use), section 109 (limitation on ozone depletion potential), and paragraphs (1), (2), (3), and (4) of subsection (d) of this section, the production, introduction into commerce, or importation of each one hundred pounds of a substance listed under section 105 that is in excess of the production limits under section 107 or section 109 shall constitute a separate violation.

SEC. 126. JUDICIAL REVIEW OF FINAL REGULATIONS AND CERTAIN PETITIONS.

Any judicial review of any fiscal action of the Administrator pursuant to this title shall be in accordance with sections 701 through 706 of title 5 of the United States Code, except that—

(1) a petition for review of any final action of the Administrator may be filed by any interested person in the Circuit Court of Appeals of the United States for the Federal judicial district in which such person resides or transacts business, and such petition shall be filed within ninety days from the date of such promulgation or denial or after such date if such petition is for review based solely on grounds arising after such ninetieth day; action of the Administrator with respect to which review could have been obtained under this subsection shall not be subject to judicial review in civil or criminal proceedings for enforcement; and

(2) if a party seeking review under this Act applies to the court for leave to adduce additional evidence, and shows to the satisfaction of the court that the information is material and that there were reasonable grounds for the failure to adduce such evidence in the proceeding before the Administrator, the court may order such additional evidence (and evidence in rebuttal thereof) to be taken before the Administrator, and to

be adduced upon the hearing in such manner and upon such terms and conditions as the court may deem proper; the Administrator may modify administrative findings as to the facts, or make new findings, by reason of the additional evidence so taken, and shall file with the court such modified or new findings and the Administrator's recommendation, if any, for the modification or setting aside of the original administrative order, with the return of such additional evidence.

SEC. 127. CITIZEN SUITS.

(a) IN GENERAL.—Except as provided in subsection (b) or (c) of this section, any person may commence a civil action on his own behalf—

(1) against any person (including (a) the United States, and (b) any other governmental instrumentality or agency, to the extent permitted by the eleventh amendment to the Constitution) who is alleged to be in violation of any permit, regulation, condition, requirement, prohibition, or order which has become effective pursuant to this title; or

(2) against the Administrator where there is alleged a failure of the Administrator to perform any act or duty under this title which is not discretionary with the Administrator.

Any action under paragraph (a)(1) of this subsection shall be brought in the district court for the district in which the alleged violation occurred. Any action brought under paragraph (a)(2) of this subsection may be brought in the district court for the district in which the alleged violation occurred or the District Court of the District of Columbia. The district court shall have jurisdiction, without regard to the amount in controversy or the citizenship of the parties, to enforce the permit, regulation, condition, requirement, prohibition, or order, referred to in paragraph (1), to order such person to take such other action as may be necessary, or both, or to order the Administrator to perform the act or duty referred to in paragraph (2), as the case may be, and to apply any appropriate civil penalties.

(b) ACTIONS PROHIBITED.—No action may be commenced under subsection (a)(1) of this section—

(1) prior to sixty days after the plaintiff has given notice of the violation to—

(A) the Administrator; and

(B) to any alleged violator of such permit, regulation, condition, requirement, prohibition, or order; or

(2) if the Administrator has commenced and is diligently prosecuting a civil or criminal action in a court of the United States to require compliance with

such permit, regulation, condition, requirement, prohibition, or order.

In any action under subsection (a)(1), any person may intervene as a matter of right. Any action respecting a violation under this Act may be brought under this section only in the judicial district in which such alleged violation occurs.

(c) NOTICE.—No action may be commenced under paragraph (a)(2) of this section prior to sixty days after the plaintiff has given notice to the Administrator that he will commence such action. Notice under this subsection shall be given in such manner as the Administrator shall precribe by regulation.

(d) INTERVENTION.—In any action under this section the Administrator, if not a party, may intervene as a matter of right.

(e) COSTS.—The court, in issuing any final order in any action brought pursuant to this section or section 125, may award costs of litigation (including reasonable attorney and expert witness fees) to the prevailing or substantially prevailing party, whenever the court determines such an award is appropriate. The court may, if a temporary restraining order or preliminary injunction is sought, require the filing of a bond or equivalent security in accordance with the Federal Rules of Civil Procedure.

(f) OTHER RIGHTS PRESERVED.—Nothing in this section, or this title, shall restrict any right which any person (or class of persons) may have under any statute or common law to seek enforcement of any standard or requirement or to seek any other relief (including relief against the Administrator).

SEC. 128. SEPARABILITY.

If any provision of this title, or the application of any provision of this title to any person or circumstance, is held invalid, the application of such provision to other persons or circumstances, and the remainder of this title, shall not be affected thereby.

SEC. 129. RELATIONSHIP TO OTHER LAWS.

(a) Nothing in this title shall be construed to diminish the authority of the Administrator under the Clean Air Act, the Resource Conservation and Recovery Act, or the Toxic Substances Control Act, or any other law, or to affect the authority of any other department, agency, or instrumentality of the United States under any provision of law to promulgate or enforce any requirement respecting the control of any substance, practice, process, or activity for purposes of protecting the stratosphere or ozone in the stratosphere, or the global environment.

(b) Nothing in this Act shall preclude or deny any State or political subdivision thereof from adopting or enforcing any requirement respecting the control of any substances, practice, process, or activity for purposes of protecting the stratosphere or ozone in the stratosphere or the global environment.

SEC. 130. AUTHORITY OF ADMINISTRATOR.

The Administrator is authorized to prescribe such regulations as are necessary to carry out this Act.

TITLE II—GLOBAL CHANGE ADJUSTMENT AND MITIGATION

SEC. 201. SHORT TITLE.

This title may be cited as the "Environmental Adjustment Act of 1988".

SEC. 202. FINDINGS.

The Congress finds that—

(a) there has been an observed increase in global average temperatures of 0.7 degrees Centigrade in the last century;

(b) regardless of any action taken by humanity, there will be further global average temperature increases of up to one degree Centigrade;

(c) such temperature increases will manifest themselves in widespread alterations of the current environment;

(d) such changes may include, but will almost certainly not be limited to, the following:

(1) a rise in the level of oceans, bays, sounds, and other bodies of water, with ensuing destruction of natural and manmade structures;

(2) shifts in patterns of rainfall and soil moisture, resulting in marked changes in agricultural productivity;

(3) changes in the distribution and seasonal availability of fresh water resources, including the exhaustion of surface and ground water supplies;

(4) increased political instability, with the potential for international conflict; and,

(5) accelerated extinction of plant and animal species, including many now classified as endangered;

(e) the adverse effects of some such changes can be mitigated through proper long range planning, analysis and, most importantly, action; and

(f) substantial resources can be saved through the adoption of a program to systematically identify the impacts of proposed actions on global environmental change and the effects of such changes on the natural environment and engineered structures and systems.

SEC. 203. AMENDMENT TO THE NATIONAL ENVIRONMENTAL POLICY ACT.

The National Environmental Policy Act of 1969 is amended by adding at the end thereof a new title as follows:

"TITLE III—GLOBAL PROTECTION

"Subtitle A—Atmospheric Protection

"SEC. 301. SHORT TITLE.

"This subtitle may be cited as the "Atmosphere Protection Act of 1987".

"SEC. 302. FINDINGS.

"The Congress, recognizing the profound and irreversible and potentially catastrophic impacts of humanity's activities on the global atmosphere and the world's environment, and the inability of science to predict with certainty the consequences for humanity of any such changes, hereby declares that each person has a responsibility and obligation to avoid contamination of the atmosphere.

"SEC. 303. AUTHORIZATION.

"The Congress authorizes and directs that, to the fullest extent possible: (1) the policies, regulations, and public laws of the United States shall be interpreted and administered in accordance with the policies set forth in this chapter, and (2) all agencies of the Federal Government shall, with respect to pollutants, substances, products, or practices which may contribute to global climate change, stratospheric ozone depletion, or trace gas modification of the atmosphere—

"(A) utilize a systematic, interdisciplinary approach which will insure the integrated use of the natural and social sciences and the environmental design arts in planning and in decisionmaking which may have an impact on man's environment;

"(B) identify and develop methods and procedures, in consultation with the Council on Environmental Quality established by subchapter II of this chapter, which will assure that environmental contamination is minimized;

"(C) include in every recommendation on report or proposals for legislation and other major actions significantly affecting the quality of the human environment, a detailed statement by the responsible official on—

"(i) the environmental impact of the proposed action,

"(ii) any adverse environmental effects which cannot be avoided should the proposal be implemented,

"(iii) alternatives to the proposed action,

"(iv) the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and "(v) any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.

Such pollutants and substances shall include, at a minimum, the following: carbon dioxide, oxides of nitrogen, chlorofluorocarbons, halons, methyl chloroform, carbon tetrachloride and methane. Prior to making any detailed statement, the responsible Federal official shall consult with and obtain the comments of any Federal agency which has jurisdiction by law or special expertise with respect to any environmental impact involved. Copies of such statement and the comments and views of the appropriate Federal, State, and local agencies, which are authorized to develop and enforce environmental standards, shall be made available to the President, the Council on Environmental Quality and to the public as provided by section 552 of title 5, and shall accompany the proposal through the existing agency review processes;

"(D) study, develop, describe and select appropriate alternatives which recognize and minimize the environmental impacts of such proposed action.

"(E) make available to States, counties, municipalities, institutions, and individuals, advice and information useful in restoring, maintaining, and enhancing the quality of the environment;

"(F) initiate and utilize ecological information in the planning and development of resource-oriented projects; and

"(G) assist the Council on Environmental Quality established by subchapter II of this chapter.".

SEC. 204. INVENTORY AND REVIEW OF FEDERAL FACILITIES, HOLDINGS AND ACTIVITIES.

(a)(1) Not later than January 1, 1990, the President shall direct each agency and instrumentality of the executive branch to undertake a systematic and comprehensive survey of all Federal lands and structures to ascertain their vulnerability to changes associated with changes in the global environment. To the maximum extent practicable, such survey shall include the lands and structures of State and local government and Indian tribes as well. Such survey shall include, but not be limited to, the following:

(A) public highways, bridges, tunnels, and other transportation structures;

(B) ports, waterways, locks and dams;

(C) public buildings and monuments;

(D) publicly owned treatment works;

(E) national parks, forests, wilderness areas, wildlife refuges, marine sanctuaries, and all other comparable facilities; and,

(F) national defense facilities, including but not limited to military bases and reservations, whether located in the United States or elsewhere.

(2) Not later than January 1, 1992, the President shall submit a report to the Congress containing the results of the survey required by this section and recommending both generic and site-specific actions and policies to—

(A) preclude further public or private investment in areas susceptible to loss or damage due to global environmental change;

(B) minimize and mitigate the loss or damage due to the global environmental change which is likely to occur.

SEC. 205. GROUND WATER PROTECTION AND RECHARGE.

(a) FINDINGS.—The Congress finds that—

(1) a consequence of global climate change may be the exhaustion of ground water resources essential to the maintenance of agricultural productivity, the loss of which could jeopardize the national economy and security;

(2) existing knowledge and technology of artificial recharge of ground water is inadequate to meet exist-

ing and anticipated future water resource problems and to take advantage of possible water resource opportunities;

(3) a program to support and assure the study and development of artificial ground water recharge techniques is essential.

(b) The Secretary of the Army (hereinafter in this section referred to as the "Secretary") acting through the Chief of Engineers, is authorized to undertake a program of research, development, and demonstration of artificial ground water recharge techniques. The purpose of such program shall be to—

(A) demonstrate the usefulness of artificial ground water recharge as a method for improving ground water quantity and for preventing degradation of, or improving ground water quality;

(B) determine the economic viability of artificial ground water recharge as a method of augmenting existing water supplies and improving ground water quality on a local or regional basis; and

(C) develop new and more efficient techniques for the transfer of surface water to existing or potential water bearing underground strata.

(3) In order to advance the purpose of this subsection, the Secretary shall, at different locations throughout the

United States, design, construct, and operate and maintain projects to demonstrate different artificial ground water recharge techniques. To the maximum extent feasible, such locations shall be chosen to reflect a variety of geological, physical, and chemical conditions affecting ground water quality and quantity. In selecting such locations, and carrying out such work, the Secretary shall consult and coordinate with appropriate State and local governmental agencies.

(c) COORDINATION.—In order to prevent any unnecessary duplication of effort, and in order to fully utilize the available expertise of other agencies and departments of the United States, the Secretary, in carrying out subsection (b) of this section, shall consult and coordinate with the United States Geological Survey, the Environmental Protection Agency, the Bureau of Reclamation, and other appropriate agencies and departments of the United States.

(d) UTILIZATION OF CURRENT RESOURCES.—To the extent possible, activities undertaken pursuant to subsection (b) of this section shall utilize existing or authorized Corps of Engineers water resources projects, programs, facilities, and personnel.

(e) REPORT.—Not later than May 30, 1993, the Secretary shall transmit to the Committee on Public Works and Transportation of the House of Representatives and the Committee on Environment and Public Works in the Senate, a final report describing the results of activities undertaken pursuant to this section. Not later than 30 months after the date of enactment of this Act, the Secretary shall transmit to such Committees of Congress a brief report describing the progress of such activities.

(f) DEFINITIONS.—For the purposes of this section, the term—

(1) "artificial ground water recharge" shall include but not be limited to techniques to supplement or otherwise affect ground water supplies such as wells, pits, ponds, spreading basins, or gravel chains; and

(2) "non-Federal sponsor" shall mean a State, city, county, or any other entity which derives its powers from a State constitution, or was created pursuant to an Act of a State legislature.

(g) SHORT TITLE.—This section shall be known as the "Ground Water Recharge Research and Demonstration Act".

TITLE III—INTERNATIONAL COOPERATION

SEC. 301. FINDINGS.

The Congress finds that—

(a) complete elimination of chlorofluorocarbons and related chemicals which are destroying the Earth's protective ozone layer and adding to global temperature increases requires concerted international agreement and action;

(b) the most effective controls on emissions of carbon dioxide, hydrocarbons, oxides of nitrogen, methane and other trace gases which are increasing global temperatures will require concerted international agreement and action;

(c) international agreements to address some aspects of these global threats are already underway and include—

(1) an international protocol to reduce production and use of chlorofluorocarbons;

(2) an international agreement to reduce emissions and transboundary transport of oxides of sulfur;

(3) an international agreement to reduce emissions and transboundary transport of oxides of nitrogen.

(d) in the absence of such international cooperation and agreement, the interests of the United States will be directly and substantially threatened due to—

(1) damage to the domestic environment;

(2) damage to the national economy;

(3) increased international tension; and

(4) increased danger of international armed conflict.

SEC. 302. INTERNATIONAL COOPERATION.

(a) the President is hereby directed to request that the United Nations promptly establish a temporary new agency to be headed by the director of the United Nations Environmental Program, to—

(1) coordinate international efforts to minimize and mitigate the effects of unavoidable environmental alterations; and,

(2) provide financial, technical and other assistance to developing nations to facilitate improvements in their domestic standards of living while minimizing or eliminating contributions to global, continental and subcontinental scale environmental damages.

(b) The President is hereby directed to request that the United Nations establish a temporary program of forestation to—

(1) assist and encourage nations in halting activities which are resulting in destruction of the world's forests; and

(2) undertake a global program of reforestation.

(c) The President is hereby directed to instruct United States representatives to bilateral and multilateral organizations other than the United Nations to review the activities of such organizations to assure that their actions and programs are consistent with the goals and objectives of this Act and, where necessary, to persuade such organizations to adopt programs to implement the goals and objectives of this Act.

TITLE IV—DEVELOPMENT OF NON-POLLUTING ENERGY SOURCES

SEC. 401. NATIONAL COMMISSION ON INHERENTLY SAFE NUCLEAR ENERGY.

(a) There is established a commission to be known as the National Commission on Inherently Safe Nuclear Energy (hereinafter in this section referred to as the "Commission").

(b) The duties of the Commission are to—

(1) assess generally the safety and reliability of the current generation of nuclear power plants in the United States;

(2) review the nuclear industries of other nations which rely heavily on nuclear power for the generation of their electricity and report on the comparative safety and reliability of the programs of those nations, which shall included but not be limited to France, West Germany, Canada, Japan, Sweden, and Finland;

(3) review each incident in the United States related to the operation of a nuclear power plant in which there has been personal injury, or a significant threat thereof, and report on the causes of conse-

quences of such incident, including ways in which it could have been avoided;

(4) review and assess the nature and magnitude of public opposition and concern with the safety of nuclear power and the reasons for such concern and opposition;

(5) evaluate options for responding to the concerns and fears of the public in a fashion which allays fears by responding substantively:

(6) evaluate the suitability of the current structure of the domestic utility industry with respect to the safe and efficient operation of nuclear units, and alternatives to such current structure;

(6) identify and evaluate each inherently safe passive control technology which might reasonably become available by the year 2010 and examine explicitly whether each such technology has the potential to minimize or eliminate the risks, whether real or perceived, associated with nuclear power by the American public;

(7) review the difference in operating records of each utility operating nuclear generating plants and make specific recommendations for changes in technologies, policies, practices, and organizational structure of the industry designed to assure that the best of

those safety records become the standard for the United States industry; and

(8) conclude and state specifically whether it is possible to develop in the United States a nuclear industry capable of supplying not less than 50 per centum of the Nation's electricity needs through the year 2100 in a way which enjoys the trust, confidence and support of the public.

(c)(1) The Commission shall be composed of nineteen members as follows:

(A) six appointed by the Speaker of the United States House of Representatives from among the Members of the House of Representatives;

(B) four appointed by the majority leader of the United States Senate from among the Members of the United States Senate;

(C) eight appointed by the President as follows:

(i) four from among a list of nominations submitted to the President by the National Governors Association;

(ii) one from among a list of nominations submitted to the President by the National League of Cities and the United States Conference of Mayors;

(iii) three from among a list of nominations submitted to the President from groups, organizations, or associations of citizens which are representative of persons concerned with pollution and environmental issues and which have participated, at the State or Federal level, in studies, administration proceedings, or litigation (or any combination thereof) relating to nuclear energy; and

(D) the Chairman of the Nuclear Regulatory Commission.

A vacancy in the Commission shall be filled in the manner in which the original appointment was made. Appointments may be made under this subsection without regard to section 5311(b) of title 5, United States Code. Not more than four of the six members appointed under subparagraph (A) and not more than three of the four members appointed under subparagraph (B) may be of the same political party. No member appointed under paragraph (C) may be an officer or employee of the Federal Government.

(2) If any member of the Commission who was appointed to the Commission as a Member of the Congress leaves that office, or if any member of the Commission who was appointed from persons who are not officers or employees of any government becomes an officer or employee of a government, he may continue as a member of the Commission for

not longer than the ninety-day period beginning on the date he leaves that office or becomes such an officer or employee, as the case may be.

(3) Members shall be appointed for the life of the Commission.

(4)(A) Except as provided in subparagraph (B), members of the Commission shall each be entitled (subject to appropriations provided in advance) to receive the daily equivalent of the maximum annual rate of basic pay in effect for grade GS-18 of the General Schedule for each day (including travel time) during which they are engaged in the actual performance of duties vested in the Commission. While away from their homes or regular places of business in the performance of services for the Commission, members of the Commission shall be allowed travel expenses, including per diem in lieu of subsistence, in the same manner as persons employed intermittently in Government service are allowed expenses under section 5703 of title 5 of the United States Code.

(B) Members of the Commission who are Members of the Congress shall receive no additional pay, allowances, or benefits by reason of their service on the Commission.

(5) Five members of the Commission shall constitute a quorum but two may hold hearings.

(6) The Chairman of the Commission shall be appointed by the Speaker of the House of Representatives from among members appointed under paragraph (1)(A) of this subsection and the Vice Chairman of the Commission shall be appointed by the majority leader of the Senate from among members appointed under paragraph (1)(B) of this subsection. The Chairman and the Vice Chairman of the Commission shall serve for the life of the Commission unless they cease to be members of the Commission before the termination of the Commission.

(7) The Commission shall meet at the call of the Chairman or a majority of its members.

(d)(1) The Commission shall have a Director who shall be appointed by the Chairman, without regard to section 5311(b) of title 5, United States Code.

(2) The Chairman may appoint and fix the pay of such additional personnel as the Chairman considers appropriate.

(3) With the approval of the Commission, the Chairman may procure temporary and intermittent services under section 3109(b) of title 5 of the United States Code.

(4) The Commission shall request, and the head of any Executive Branch Agency is authorized to detail on a reimbursable nonreimbursable basis, any of the personnel of their respective agencies to the Commission to assist it in carrying out its duties under this section.

(e)(1) The Commission may, for the purpose of carrying out this section, hold such hearings, sit and act at such times and places, take such testimony, and receive such evidence, as the Commission considers appropriate.

(2) Any member or agent of the Commission may, if so authorized by the Commission, take any action which the Commission is authorized to take by this section.

(3) The Commission may use the United States mails in the same manner and under the same conditions as other departments and agencies of the United States.

(4) The Administrator of General Services shall provide to the Commission on a reimbursable basis such administrative support services as the Commission may request.

(5) The Commission may secure directly from any department or agency of the United States information necessary to enable it to carry out this section. Upon request of the Chairman of the Commission, the head of such department or agency shall furnish such information to the Commission.

(f)(1) The Commission shall transmit to the President and each House of the Congress a report not later than October 30, 1994. The report shall contain a detailed statement of the findings and conclusions of the Commission with respect to each item listed in subsection (b), together with its recommendations for such legislation; and administrative actions, as it considers appropriate.

(g) The Commission shall cease to exist on January 1, 1995.

(h) There is authorized to be appropriated for the fiscal year 1989 through 1995 not to exceed $50,000,000 to carry out this section.

SEC. 402. NATIONAL GOAL.

It is hereby established as a national goal of the United States to derive 50 per centum of the national supply of energy from nonpolluting technologies and practices by the year 2000 and 100 per centum by the year 2050.

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THE GLOBAL CLIMATE PROTECTION ACT OF 1988

FRIDAY, SEPTEMBER 16, 1988

U.S. SENATE, COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS, SUBCOMMITTEES ON HAZARDOUS WASTES AND TOXIC SUBSTANCES AND ENVIRONMENTAL PROTECTION,
Washington, DC.

The subcommittee met, pursuant to notice, at 10:36 a.m., in room 406, Dirksen Senate Office Building, Hon. Max Baucus [chairman of the subcommittee] presiding.

Present: Senators Baucus, Chafee, Stafford, Mitchell, Pressler, Durenberger, and Graham.

OPENING STATEMENT OF HON. MAX BAUCUS, U.S. SENATOR FROM THE STATE OF MONTANA

Senator BAUCUS. The hearing will come to order.

On Wednesday, this committee held a hearing on some of the consequences that are connected with the phenomenon of global warming. At that hearing and at earlier hearings, the committee heard from witnesses who very clearly testified in their belief that a global warming phenomenon is occurring and secondly, that a lot of the adverse consequences that we are now experiencing in the earth, namely more intense hurricanes, drought, and ocean warming could very well be caused by the phenomenon of global warming and that certainly it is consistent with models and theories that would so indicate.

The point of today's hearing is to explore solutions, that is, how to reduce CO_2 emissions in particular. We are not going to focus today so much on chloroflourocarbons, methane or other greenhouse gasses, but rather focus primarily on carbon dioxide as the principal greenhouse gas. What can we do in this country in a feasible, realistic, practical sense that will make a significant, meaningful contribution to the reduction of carbon dioxide emissions in this country? We may also get a bit into the questions throughout the rest of the world so that we can begin to try to address the global warming phenomenon.

We have several witnesses today who will focus on that point, the feasibility and the ways that we can begin to achieve some practical results. We are not going to focus today on CFCs or other greenhouse gasses, but only on carbon dioxide as a principal greenhouse gas.

Our witness list consists of Dr. Irving Mintzer of the World Resources Institute; Mr. James Tacheny, Northern States Power Company of Minneapolis, Minnesota; Dr. William Chandler, Batelle-Pacific Northwest Laboratory in Washington, D.C.; Mr. David Freeman, Lower Colorado River Basin Commission; Ms. Deborah Bleviss, the International Institute for Energy Conservation and Mr. Meyer Steinberg, with Brookhaven National Laboratory. Would you all please come to the witness table?

I have a statement that I will place in the record at this point.

[The statement referred to follows:]

OPENING STATEMENT OF HON. MAX BAUCUS, U.S. SENATOR FROM THE STATE OF MONTANA

Today's hearing is the second in a series of hearings on the Global Climate Protection Act. On Wednesday we learned how serious a problem global warming is. Today we will learn about what can be done to address it.

The Global Climate Protection Act, which Senator Stafford and I introduced earlier this year, calls for a 50 percent reduction of carbon dioxide emissions from 1985 levels. The Office of Technology Assessment has concluded that this goal could be reached by the year 2030.

It is this goal that we as a Nation need to set.

No doubt there will be those who will say the legislation goes too far. However, our goals must be amibitious if meaningful results are to be achieved.

The legislation is structured to take small, achievable steps during the early years after its enactment. OTA, in their analysis of the bill, states "the majority of the efficiency levels specified by S. 2666, through (the year) 2010, are achievable with current technology."

In later years, the standards called for in the legislation will be tougher. Much as the Clean Air Act in 1970 challenged the auto industry to clean-up its tailpipe emissions with new technology, this legislation challenges U.S. industry to develop new innovative ways to protect our climate.

In short, there is challenge, there is opportunity, and there is risk in this legislation.

The United States is the single largest contributor to the global climate problem. If we are unwilling to take the high road and address the issue, it is unlikely the rest of the world will. This is the challenge.

Those who find ways to address the problem, whether through making their economies more efficient or developing new technologies to control greenhouse gases, will increase their competitiveness. This is the opportunity.

If we fail to act and earth's climate warms, its timber resources become scarcer, and our shorelines will erode. This is the risk.

On Wednesday some of the most distinguished scientists on this issue testified that while all the "I's" were not dotted and the "T's" not crossed, the circumstantial evidence was overwhelming. Greenhouse gases are warming the earth. And we could expect dramatic unpredicted effect, just as no one predicted the existence of an ozone hole.

There was unanimous agreement that drought, extreme forest fire damage, massive crop failures, flooding in Bangladesh and intensified hurricanes were consistent with what one would expect from greenhouse induced warming.

As we begin today's hearing, the most intense tropical storm on record, Hurricane Gilbert, is raging; over 69,000 fires have burned a total of 4 million acres and the worst of the fire season is yet to come in California.

We can act or nature will act for us. There is time to make a choice, but time is running out. It is my intention to press for early effective action by Congress. The U.S. must recognize its responsibility and put the full force of its technological might behind solving this problem.

Before we begin, I want to call attention to a hearing that the National Highway Traffic Safety Administration held earlier this week. This hearing focused upon whether or not fuel efficiency standards should be held at 26 miles per gallon rather than be increased to 27.5 miles per gallon.

Two of our major auto makers—General Motors and Ford—asked that fuel economy standards be loosened to allow them to continue producing gas-guzzlers. Chrysler, to its credit, will meet the 27.5 mile per gallon standard.

The forest fires, crop failures, drought and hurricanes are warnings . . . warnings about what global warming will bring. Now is not the time to ignore that signal. Backing off on CAFE standards would send the wrong signal to the American public and the world.

I would like to welcome today's witnesses and call them to the witness table at this time. I look forward to learning of their solutions to the greenhouse effect.

Senator BAUCUS. Before we hear from the witnesses, I would like to ask if any of the committee members have statements to make. I will first ask the very able cochairman of this effort, Senator George Mitchell who chairs the Subcommittee on Environmental Protection and is a leader on this issue as well as many others.

OPENING STATEMENT OF HON. GEORGE J. MITCHELL, U.S. SENATOR FROM THE STATE OF MAINE

Senator MITCHELL. Thank you, Mr. Chairman. I will ask that my statement be placed into the record so that we may get to the witnesses. I do again commend you for calling for and holding this series of hearings. Thank you.

[The prepared statement of Senator Mitchell follows:]

OPENING STATEMENT OF HON. GEORGE J. MITCHELL, U.S. SENATOR FROM THE STATE OF MAINE

Last Wednesday we heard from a panel of witnesses who testified about the likelihood and implications of global warming. The compelling conclusion of the testimony is that we must act now to curb the expected increase in the earth's atmosphere. Failure to do so could make 1988 the beginning of a trend in extreme weather patterns that affects our health and safety, our agriculture and our fishing patterns.

In order to avoid disaster, we must dramatically reduce our emissions of carbon dioxide. Carbon dioxide is a product of fossil fuel combustion, including power plants, automobiles and is related to our electricity demand. This pollutant has so many sources that a broad range of controls must be contemplated. How to reduce these emissions is central to any policy to restrain global warming.

The witnesses today I hope will chart a course for us to regain control over emissions of greenhouse gases. There are steps we can take today to address the issue. There are currently available energy efficient appliances, homes, and cars.

We can choose to spend our money in a way that is consistent with our environment. Before our next purchase of energy-consuming items we can and should pause to consider if this selection best meets our personal needs and the needs of the planet.

Additional measures are needed. But we do not have to wait for Congress to act to turn off unneeded lights or use energy efficient light bulbs and appliances.

Senator BAUCUS. Senator Stafford?

OPENING STATEMENT OF HON. ROBERT T. STAFFORD, U.S. SENATOR FROM THE STATE OF VERMONT

Senator STAFFORD. Thank you, Mr. Chairman. I am very glad to be here and as I have said before, I not only thank the two cochairmen for holding this committee hearing, but in Senators Chafee, Mitchell, and Baucus, in the judgment of this Senator, we have three of the five Senators who have been key players in every environmental endeavor of this committee over the last 8 or 10 years. I know that they are going to carry on well in the next Congress.

This should be a good morning. I know that David Freeman is one of the people who will be a witness this morning, and I think that he knows as much about energy policy as any man in America and probably more than most. Within arm's reach of Mr. Freeman is Northern States Power, a utility that has consistently been the first: the first wet scrubber, the first dry scrubber, the first fluidized bed combustion, and many say the best nuclear program in the United States. Also, we will finally start discussing solutions: 60 mile-per-gallon Volvo's, smokeless coal technologies, and other things that really work.

Soon will come the next step. The next step will be that opponents will stop saying that the task is impossible and start saying that it costs too much. It is in this context that the Senator from Vermont would like to make one or two brief statements.

First, he would like to urge the many men and women whom he has come to know over the years not to treat this legislation as if we were engaged in business as usual. Congress is not dealing with finite and confined threats such as those posed by the pollutants and chemicals regulated under the Clean Air Act, the Clean Water Act, Superfund, and many other laws which have been written into the statute books in the last two decades.

Addressing this problem will seem expensive when the cost estimates finally are available. Doing something always seems expensive when compared to doing nothing or doing very little. But how will those costs compare to the $7 billion in damages in Jamaica due to Hurricane Gilbert or to the scores of deaths from flooding in Bangladesh, or the loss of forests older than the United States due to fire and pollution? There can not be business as usual if there is no business left to do. That is the magnitude, in the opinion of this Senator, of the threat facing this Nation and indeed the entire globe. Even all of the governments of the world acting in concert can not solve the problem alone. It will require the cooperation and collaboration of business and industry, and I hope that will be forthcoming.

As the legislation enters the next stage, there will be a constant temptation to change it in ways that seem more reasonable and more flexible. In every environmental law in which this Senator has worked save one, the Congress has yielded somewhat to those temptations. The result is a collection of laws which I have, I regret to say, found and proven to be less than complete successes. The sole exception has been the automobile emission standards of the Clean Air Act, due largely to the insistence of Senator Muskie, a man whose determination, resolve, and I might say occasional displays of some light temper many of us know well.

Senator MITCHELL. Cancel that word "light."

Senator STAFFORD. The Congress wrote explicit numbers and dates into that law. As a result, the program has worked and worked well. Progress made in the United States and the rest of the world in curbing air pollution is largely because of those numbers and dates. They simply could not be evaded or avoided. Such success can not be attributed to any other law or provision on the books. Just one example is lead, which is a toxic in every known form and of utterly no nutritional value. I even remember coaches asking me to get it out of a certain part of my anatomy.

Lead continues to be sold in gasoline today at virtually every service station in America. For nearly two decades the Nation has been committed to removing lead from gasoline because it destroys the intelligence of children and kills men through stroke and heart attack. Congress has been unwilling to ban the sale of leaded gasoline outright and the Administration—every administration, not just this one—has displayed a similar lack of courage. The result is air which, while much improved, still contains some serious contaminants.

S. 2666 contains numbers and dates. Where necessary, dates should change and so should numbers, but whatever those changes might be, specific dates and exact numbers should be retained. Otherwise, it is likely that this will be another law which is only partially successful. In the judgment of this Senator, there is no room for failure here.

Thank you, Mr. Chairman.

Senator BAUCUS. Thank you very much.

Senator Chafee?

OPENING STATEMENT OF HON. JOHN H. CHAFEE, U.S. SENATOR FROM THE STATE OF RHODE ISLAND

Senator CHAFEE. Thank you, Mr. Chairman. Unfortunately, I have a conflict. I must leave and then come back later, but I do want to say that I congratulate you and Senator Mitchell again for these hearings. I think that the hearing that we held Wednesday was excellent and the scientists there were telling us that by the time we can give a definitive answer, it will be too late. We have these headlines of one natural disaster after another and the tendency is to take it in stride and say, "This too shall pass." The problem is that disaster is truly looming on the horizon for all of us as inhabitants of this small sphere called Earth, and it will consume us if we do not wake up and stop polluting the environment.

One final point: at Wednesday's hearing, Mr. Chairman, Dr. Cicerone raised an issue that I think is critical to the whole effort. That is the issue of leadership, and Dr. Cicerone said that it is important for the United States to take the high ground and reassert ourselves as world leaders in this and in all environmental matters. I feel very strongly about that, Mr. Chairman, and I believe that the thrust has got to come, as it has in past, from this committee. We are the only environment committee in the Congress and we have a great position of leadership. We can continue to assert that leadership and press the Administration, no matter which administration it is, to get the United States right out in front and assume the world leadership in this role.

Thank you, Mr. Chairman.

Senator BAUCUS. Thank you.

Senator Pressler?

Senator PRESSLER. Mr. Chairman, I join in the congratulations to you and the witnesses on these important hearings. I have three committees meeting simultaneously this morning so I cannot remain. Thank you.

Senator BAUCUS. Thank you, Senator.

Senator Durenberger?

OPENING STATEMENT OF HON. DAVE DURENBERGER, U.S. SENATOR FROM THE STATE OF MINNESOTA

Senator DURENBERGER. Mr. Chairman, it appears that the Senate is going to take up legislation to reauthorize and amend the Clean Air Act one of these days. We may even get lucky and have it end up with the President, although that may well be stretching it this year. But even if that miracle came about and even if we passed S. 1894, the Clean Air Standards Attainment Act as it is now written, we all ought to expect to be right back here in this hearing room next January to begin this job of doing something about air pollution all over again. That is because, as we have been trying to demonstrate throughout most of the eighties, the threat to our atmosphere is now understood to be much larger than the scope of the current Clean Air Act and larger even than the aggressive program that is outlined in S. 1894.

The twin problems of global warming and destruction of the ozone shield will surely capture the attention of the next Congress. Two major legislative proposals have in fact been introduced, and while we look forward to the possibility of crafting a legislative response to protect the global processes, such as ocean currents, world agricultural harvests, and forest growth and decline as described Wednesday, it strikes me, Mr. Chairman, that we are going to need some very different tools than the ones that we have relied on in the past. I think there will be a real challenge to this committee and to our colleagues to see if we can think in new ways in order to protect our environment.

For instance, I believe that the necessary response to global warming will require a substantial reduction in carbon dioxide emissions by the Nation over the next decade or so, something on the order of at least 25 percent less CO_2 emission. I have no doubt that we can afford to make that kind of reduction and that we have the technical know-how to go about it. The question is simply: can we get organized socially to take that job on? Here we are not talking about end-of-the-pipe pollution control technology which we require some industry or city to install on the top of a stack or the end of a sewer, and it is not some new-fangled fission reactor that is going to solve the problem. There are no hard-technology magic bullets for this particular problem. Rather, it seems to me, that we need to make major changes in the small decisions that everybody makes every day: millions of small steps that add up to the giant step to protect mankind and our globe.

When I came to the Congress in 1979, our first big legislative experience was the design of an energy policy and in particular the design of the windfall profits tax from the Senate Finance Committee. We spent weeks designing government programs to encourage conservation, such as using alternative energy sources and finding ways to spend all those hundreds of billions of dollars that we knew were going to come in. And I am convinced after that experience and after all that effort, that we really did not make a dime's worth of difference from the solar tax credits to the synthetic fuels corporation. Government spending accomplished virtually nothing on the energy question in the late seventies and the early eighties. Price de-control is what really did the job. So our economy today is substantially more energy efficient than it was in 1978 when we were elected, and that is 99 percent due to higher pricing. We sent out a signal to everybody in America and got millions of people marching together to take small steps in the right direction.

Mr. Chairman, I am not even a cosponsor of the bill that our colleague, Senator Wirth, has introduced on the global warming problem. I was an active participant here in the Congress in shaping the Carter Energy Program, and that experience cured me once and for all on the tax credit, the demonstration program, and the feasibility study as a means to make major changes in something so fundamental as energy economics. And I do not even have an alternative global warming program to launch today, which I should in the middle of a political campaign, because I do not yet see a way to turn it all around and march down the hill of energy consumption to some level of 20 or 25 percent lower by the year 2000, but I am ready, as the members of this committee are, to think in new ways because we have all come to the conclusion that it is absolutely necessary to do that.

The second point that I want to make, Mr. Chairman, is that I wonder if we are well enough organized to do this job. A lot of what gets done in government depends on how the boxes on the organizational chart are arranged. You know that I introduced a bill to elevate EPA to cabinet status a little while ago, and I am certainly pleased that Senator Stafford has included that legislation in his Global Environment Protection Act. It seems to me that we need to make a commitment to pass that bill next year, but it is not simply putting EPA at the Cabinet table that is going to solve the organizational problem. The climate question is spread over several Cabinet agencies. We need to make sure that they work effectively together to address the problem. They are not doing that today and there is no question about that. In fact, there is a bit of a squabble going on that if left to fester is going to slow our national response and diminish our commitment.

When I think of the organizational problem, Mr. Chairman, I even wonder what role this committee of the Congress can appropriately play. We need to make a substantial near-term commitment on behalf of the Nation to substantially reduce our emissions of the trace gasses that lead to greenhouse warming, but even our best efforts will be swamped by economic development in the rest of the world in the long run unless they too make a commitment. Providing the kind of world leadership that moves the whole of mankind forward together is not something easily accomplished in a subcommittee hearing. We need a president to do that, and we will need to support the President who does. Both of our candidates will need to go much farther than they have yet committed if we are going to make progress globally in the next Administration.

I will just conclude, Mr. Chairman, by saying that I also worry, and I have for a long time, about the long time-frame over which our commitment has to be sustained. Setting and steadily pursuing a course for 15 or 25 years is not something that the United States of America does very well. On occasion, like the man on the moon by the end of the decade, we have been able to accomplish it, but more often, like the synthetic fuels corporation, the commitment fades with the headlines. From what we have learned, the climate problem is not going to get steadily worse year by year. It will come and go in cycles which will surely deepen if we do not act, but which also will not be reckoned in sustained calamity over a long period of time. In other words, droughts come and go and hurricanes come and go. Yellowstone fires come and go along with all of the other stuff that we talked about on Wednesday. The record is pretty clear on that.

It just seems to me that we face a real challenge, something which is much tougher even than the acid rain wars, which we hope are being concluded, and the next war is going to require a new strategy and a different approach which we have yet to identify. The good side is, that knowing the members of this committee, particulary knowing the Senator from Montana, the Senator from Rhode Island, and the Senator from Maine, the people who have been leading this effort and who are going to be here next year, I would like to encourage the people at least in this room, that what I have had to say here this morning has not fallen on deaf ears.

Thank you, Mr. Chairman.

Senator BAUCUS. I thank the Senator for that very thoughtful statement.

Let's begin with Mr. Tacheny.

Senator DURENBERGER. Jim Tacheny is from Northern States Power, but he is really from Litchfield, Minnesota. He left there to go to St. John's University, which has been my home all of my life. He was a great wrestler and then he turned to physics, and now is a frequent and good witness before this committee, much relied upon for his good judgment, Mr. Chairman. Thank you.

Senator BAUCUS. Thank you, Senator.

Mr. Tacheny, with that introduction you are off to a good start.

STATEMENT OF JAMES R. TACHENY, NORTHERN STATES POWER CO., MINNEAPOLIS, MN

Mr. TACHENY. Mr. Chairman and Senators, thank you for the opportunity to appear today. I wish that my testimony could offer you some specific solutions to the problem.

Northern States Power Company has been and will continue to be an environmental leader in the utility industry. We have taken steps voluntarily and with regulatory bodies to insure that we meet out customer demand for electricity in an environmentally sound manner.

NSP and the utility industry are certainly also aware of the increasing concerns surrounding global warming. We recognize the growing scientific consensus that greenhouse gasses will cause global warming in the future. I am sure that it is no surprise to you, but there are many significant uncertainties that remain. We do not yet understand the magnitude of the greenhouse effect, when the impacts will be felt, the severity of the problem, or the potential impact on specific geographical regions around the world.

What do we know about the greenhouse effect? At NSP specifically, we know that carbon dioxide is a major contributor of perhaps as much as 50 percent. Since in my job at the company I have responsibility for burning fossil fuels, that is a high concern in my area.

We burn significant amounts of coal, oil, and natural gas and therefore, we contribute significant amounts of CO_2. The estimates are that about 28 percent of the CO_2 emissions in the United States are from the production of electric power. Transportation contributes about another 30 percent, and other industries contribute about 24 percent. However, it is important to remember that CO_2 generation is indeed a global problem.

The United States' electric power generation contributes about 7.5 percent of the world contribution of CO_2 emissions. If we assume therefore, that we were able to cut in half the total of greenhouse gas from utilities, it would amount to about a 4 percent reduction in the world total. In other words, even if the United States' utilities severely limited CO_2 emissions, the effect on global warming would be negligible. Nevertheless, it is an important factor and as mentioned we feel that the United States and the utility industry in the United States has to help in assuming that leadership position in determining where we go.

My statements are not intended to portray a do nothing attitude by NSP or by the utility industry. We believe that there are prudent, cost-effective, and environmentally conscientious measures that can and should be taken now.

The first and probably the most important item is to increase research, that we may understand more about this phenomenon and more about the ways in which we can control it. NSP is committed to energy conservation, which we believe is another way to help in this battle. The second factor is that we have long advocated energy-efficient standards for appliances and have to date given out about $13.8 million in rebates to our residential and commercial customers for selecting energy-efficient appliances and equipment.

During the past four years, conservation and load management has displaced about 190 megawatts of generating capability in our system, and we estimate that energy conservation on our system will displace the need for an additional 190 megawatts by the year 1995.

The third factor in attacking this problem is increased efficiency in generating units to reduce the emission of greenhouse gasses. One alternative to central station generating plants where fossil fuels are burned at thermal efficiencies of about 35 percent would be to have what we have termed coproduct plants. Simply stated that is where two plants share the use of the same fossil fuels, thereby attaining thermal efficiencies of from 50 to 90 percent or higher. For example, co-product plants involving petro-chemicals, metals or petroleum extraction from coal, can be combined with the generation of power and gain significantly higher efficiencies in the burning of the fuels than those that are used, therefore reducing the CO_2 emissions significantly. Future technologies such as fuel cells might also increase efficiencies.

Our available generating resources in 1987 were 7,500 megawatts at Northern States Power Company. We supplied about 31 million megawatt-hours of energy during that year. NSP relies on coal, nuclear, and hydro-electric energy production from domestic sources and from Canada, and we will continue to use these means. In total therefore, our nuclear provides about 50 percent of our energy, which is of course a non-CO_2 emitting source. One further thing that we think can and should be done is to look perhaps toward biomass as a source of fuel, which does not reduce the output of CO_2 emissions but at least keeps the CO_2 in balance: that is, you are burning as much CO_2 as is being consumed in the biomass process.

In conclusion, legislation currently under consideration in the Global Environmental Act of 1988 contains CO_2 emission limits which we do not believe are achievable with present technology. Future policy and regulatory decisions must revolve around technology that is reasonable in reducing CO_2 emissions. I stated at the outset, Mr. Chairman, that I do not have specific answers for the problem, but we can and must take actions that we know will work today. We must significantly increase both industry and government research to better understand the greenhouse effect; we must look to energy conservation; we must develop new technologies to minimize the releases of CO_2 and we must decide whether or not we want to revive the nuclear option in our industry. Finally, we must resist the temptation to impose emission limits when we do not know whether they are achievable or even effective with today's technologies.

I hope that my comments are useful to you and your colleagues and thank you again for the opportunity to speak.

Senator BAUCUS. Thank you, Mr. Tacheny, and we will have questions at the conclusion of testimony.

Mr. Steinberg, you are next.

STATEMENT OF MEYER STEINBERG, BROOKHAVEN NATIONAL LABORATORY, UPTON, LONG ISLAND, NY

Mr. STEINBERG. Mr. Chairman, thank you for inviting me to this committee hearing today.

We, as research chemical engineers in Brookhaven National Laboratory, have been studying over the past several years means of mitigating the global CO_2 greenhouse effect, which includes removal, recovery, utilization, and disposal of CO_2 from fossil fuel-burning plants. These studies have been made for the Carbon Dioxide Research Division (CDRD) of the Department of Energy (DOE), headed by Dr. Fred Koomoroff.

We can remove and recover CO_2 by known technical means from fossil fuel plants. The problem is utilization and storage. What do we do with the gegatons of CO_2? One must remember that in the United States we generate about 18 times more carbon dioxide per capita per year by weight than we generate in terms of garbage in municipal solid waste, which is about one ton per capita per year.

One thing that we can do is to improve the efficiency of utilization of fuels, improving energy technologies especially in fossil fuel utilization, and it is very worthwhile to do so. Not only do we reduce the CO_2 when we do this, but we also get a return of the investment due to lower fuel bills. Of course, we can go all the way to nuclear and solar, thereby not generating any CO_2.

I would like to present here a new technical option for the coal industry in dealing with the carbon dioxide greenhouse effect. The option concerns a "hydrogen economy" based on coal. Traditionally, the so-called hydrogen economy is based on nuclear and solar: that is, electrolytically decomposing water by means of the energy produced from nuclear and solar into hydrogen and oxygen and using hydrogen as a fuel. As we know, hydrogen is the cleanest form of fuel available today, since the only product of combustion is water.

We have developed a very efficient process called Hydrocarb, which effectively splits coal into carbon and hydrogen. The process can be described in detail, but I will just outline its advantages today. We are suggesting that coal refineries be built based on this technology. You have to remember that coal is not carbon alone, but that it consists of carbon and hydrogen. The original thrust of this process was to produce a very clean form of coal called Carbon Black from coal and from other fossil fuels, including oil and gas, for use in both in mobile and stationary heat engines. A co-product of this process is a hydrogen-rich gas. If one is concerned about the greenhouse effect, then either we use only part or none of the carbon, holding that back and using only the hydrogen as a fuel. If one desires to obtain the ultimate and eliminate all CO_2 emissions from coal, then all of the carbon can be stored and all of the hydrogen used alone.

The economic penalties of doing such a thing may be very severe, but probably not any more severe than going all the way to a nuclear option. Furthermore, this option is still open for utilizing the clean carbon at a later date because the carbon would be placed in monitored retrievable storage—and we know where we heard that one before. [Laughter.]

Should the greenhouse effect be found to be a myth in the future, the carbon could be taken out of storage in the original mineral and utilized as a clean fuel. The impurities have been previously removed: that is, the Carbon Black has no ash or sulphur in it so it would not have to be cleaned any further. This concept can be valuable to the coal industry in response to the arguments of the anti-coal critics when invoking the greenhouse effect. Of course, the proposal here can be applied to all forms of carbonaceous fuel, including oil, gas, and also waste or garbage. In this regard, we believe that this process is unique. No other process can make these claims. We are convinced that the Hydrocarb process would be of substantial benefit economically and environmentally, let alone psychologically, to the coal industry. Thank you.

Senator Baucus. Thank you very much, Mr. Steinberg.

Ms. Bleviss, you are next.

STATEMENT OF DEBORAH BLEVISS, INTERNATIONAL INSTITUTE FOR ENERGY CONSERVATION, WASHINGTON, DC

Ms. Bleviss. Thank you very much, Mr. Chairman.

I have been asked to address the issue of what can be done in the transport industry, and I would like to preface my remarks by commending the members who introduced the bill and who looked at CO_2 emissions insofar as trying to find a way of controling this emission problem and in particular, the greenhouse problem contribution from the transport industry.

I would like to point out that the remarks I am about to make are culled from a study I undertook from 1985 through 1987 that really looked at assessing what kinds of fuel economy technologies are out there for the transport industry and how feasible they are to be put into production in an expeditious manner. That study has now been published in a book which was just released last month (The New Air Crisis and Fuel Economy Technologies, Quorum

Books, 1988). I also should say that with regard to the transport industry, certainly for the next 15 years, the major strategy to reduce CO_2 emissions for that industry lies in fuel economy. Almost none of the current alternative fuels that are suggested as possibilities could realize the types of CO_2 reductions that are being proposed not only in your bill but by others as well.

The issue then is: can we do that? Can we achieve significant increases in fuel economy? The results of my study show that there are an incredible number of technologies out there. In essence, the technology revolution that has occurred over the last 20 years has only begun to be applied to light vehicles. If pursued aggressively, we could see significantly more efficient vehicles by the end of the century and indeed well into the next century.

To give you an example of some of the types of technologies underway and my estimates under a very aggressive strategy as to when they could be introduced, I call your attention to the second table in my prepared testimony. You can see again that there are a plethora of technologies available.

As for what they could produce in terms of fuel economy, we have also benefitted in the last 10 years by having quite a few companies come forward, often with cost-sharing assistance from their governments, with high-efficiency prototype vehicles. Senator Stafford mentioned one, the Volvo LCP2000, which was brought out about three years ago. There are also quite a few others. You will note, however, that they are disproportionately brought out by European companies and not American companies.

The question then of technological feasibility is not really a very big question. The bigger question is: can we bring these technologies forward in an expeditious manner? And that is the major question that I would like to address today. Virtually all of the forces that could increase the rate at which these technologies are being pursued, developed, and brought into production are working against expeditious introduction and not for it. Let me just tick down the list. We know quite a few of them already.

Low oil prices clearly have discouraged much of the fuel economy research and development and certainly much of the commercialization that were driving forces early in this decade.

Another problem is competitive forces. Competition is driving some fuel economy development in Europe and some in Japan, but unfortunately, the nature of our market has not allowed for very strong competition largely because our manufacturers have chosen basically to cede their smaller car lines--where one tends to concentrate on fuel economy research—rather than to concentrate on trying to make their smaller cars more competitive with what the Japanese and the Europeans are bringing in.

The last area, the area of government push, is probably one of the saddest. Senator Chafee referred to leadership before, and the U.S. was truly a leader in the 1970's in terms of establishing priority for fuel economy in the world. As a result, quite a few laws were passed and not only that, but quite a few countries followed the U.S. lead. As you are well aware, most of those fuel economy programs are currently being dismantled or are being weakened significantly.

The issue then is: what can we do in such a market? And I think that the proposals in your bill are a very good start, but I also think that we have learned a lot in the last 15 years of fuel economy policy about promotion, incentives, et cetera, which could well be incorporated in this bill and make it more likely that the industry will want and will in fact meet the standards that exist.

Let me very quickly go down the list of suggestions. The first one is to set very reasonable standards for the industry. I do not mean low standards or standards that the industry calls for, but I think that we have to recognize that the industry has basically "punted" on fuel economy for at least the last eight years and has not really pursued technology. So we really need to talk about realizable standards from their perspective. That, in my estimate, is something like 45 miles-per-gallon in ten years for new cars and 35 miles-per-gallon for new light trucks. We could push it somewhat higher but it should be around that level.

Second, we should set flexible goals for the industry. Requiring them to increase the efficiency of all of their cars simultaneously is probably the most expensive way to go. Instead, setting some sort of average efficiency for their fleet and allowing them to concentrate perhaps first on their large cars and then on their smaller cars, so long as they meet the average efficiency milestones, is both a less expensive way to go and also a way that is considered less risky by them.

Third, research and development really has to be supported. The American industry, from my research, is clearly lagging its competitors and these competitors are not doing as well as they could either. A supplemental R&D program is really something we should be thinking about, cooperatively shared, obviously.

Fourth, incentives and disincentives for consumers are critical. A major reason why we are lagging in fuel economy right now is that consumers are not demanding it. The types of things that we should consider are strengthening the existing gas-guzzler tax which discourages the purchase of gas-guzzlers, offering a rebate for the purchase of highly efficient cars, and also considering the price of fuel altogether.

Finally, I would like to point out that we should really concentrate on consumer information programs. These, too, have been pulled apart or weakened significantly in the last 8 years. Consumers cannot make wise decisions in a market place that does not provide them with adequate information.

With that said, I would like to commend again the cosponsors of the bill. Thank you.

Senator BAUCUS. Thank you, Ms. Bleviss.

Mr. Freeman.

STATEMENT OF DAVID FREEMAN, LOWER COLORADO RIVER BASIN COMMISSION, AUSTIN, TX

Mr. FREEMAN. Thank you, Mr. Chairman. It is a special privilege for me to appear before this committee since this is the committee that sort of sent me down to Tennessee to run the Tennessee Valley Authority for seven years. This is my first chance to appear before you since I left TVA in 1984.

If I may, in addition to my own prepared statement, I would like to offer for the record an energy policy statement that the Environmental Energy Study Institute Board of Directors unanimously adopted this week. I am a member of that board and I believe that the statement would be helpful to the committee.

Senator **Baucus**. Without objection, so ordered. (See p. 320.)

Mr. **Freeman**. Thank you.

My appearance today is a personal one. I come before you as a person who spent seven years running the Nation's largest electric utility, the Tennessee Valley Authority, which, by the way, consumed over 20 million tons of coal per year during that period and continues to do so. Before I was appointed to TVA in the early seventies, I directed the Nation's still most comprehensive study of energy consumption back in 1973, sponsored by the Ford Foundation. We did the research to document that conservation was indeed a very large and economical source of power. I therefore say to you, as someone who has been on the firing line and had to meet a utility payroll, so to speak, that we can indeed reduce the accumulation of CO_2 in the air if we have the willpower and the laws to do it.

We can cut back in a way, in my view, that can strengthen America, not weaken it. We can build the equivalent of thousands and thousands of megawatts of power plants through investments in conservation. I say this with a great deal of conviction because I carried out my promise to this committee, and in the years 1977 through 1984, the Tennessee Valley Authority did reach one million people with our energy conservation program and we did build the equivalent of a 1,000 megawatt power plant at a very small fraction of the cost of what a powerplant would have cost if we had built it on the basis of nuclear or coal.

Conservation was a good idea back in the early seventies. It is no longer an idea—it is a reality. Utilities across this Nation, from Pacific Gas and Electric, Northern States, New England Electric—utilities all over the country are implementing conservation. They do it at a pace that reflects the degree of direction that they get from their regulatory authorities and from the Congress. These companies have been in the business of selling electricity all of their lives and selling conservation does not come natural to them, but they do it.

Let me say, as someone who has followed the subject rather closely for a couple of decades, that the evidence before this committee is overwhelming that the climate change problem now has enough probability of relationship to the buildup of CO_2 that it is prudent for the Congress to take action. The evidence is much stronger than you had before you in the early seventies when the Congress unanimously passed the Clean Air Act and the Clean Water Act. There are people who will come before you and say that there is no proof positive, and if the water was up to the top of the Washington Monument, they would say that the sunk costs are too great and that on a marginal basis the rest of the planet is not worth saving.

Those people have made that testimony time and time again, and if you had listened to them, there would be no scrubbers on power plants, there would be no pollution control devices on automobiles, and the conservation ideas that were advanced in the early seventies would still be gathering dust on library shelves. Despite their noisy refrain that there is no problem and it costs too much to fix it, companies do obey the law, especially if it is enforced.

If Congress will assert the public interest by enacting legislation, it will find that just as with scrubbers, just as with conservation, and just as with fuel economy, it can be done and it can be done economically. We reduced the emissions of sulphur oxide from the Tennessee Valley Authority in half—we cut one million tons of sulphur oxide out of the air, and in the process we improved the fossil fuel plants. And it turned out after I left TVA, that those were the plants that carried the load when their nuclear plants were all shut down for various safety problems. The things that we do in the name of the environment, most often turn out to be very worthwhile for the global community as well.

Let me issue this warning, if I may. A single purpose, blind reaction to the global warming threat could resolve one problem at the expense of exacerbating another. I am old enough to remember when atomic energy was advanced by the Sierra Club as a clean alternative to western dams. The whole world knows better now. I am not opposed to nuclear power, but increasing the risk of a nuclear meltdown is no way to save the planet from an unlivable climate, and I think that those who propose relaxing the safety laws on nuclear are anti-nuclear, in my view.

The most promising source of energy, the fundamental response to the greenhouse effect, to the acid rain problem, to our other air quality concerns, to the threat to our economy from oil imports and to the dangers associated with nuclear power production are all one and the same. They are to make conservation the centerpiece of our energy and environmental policy. It is going to take laws to make that happen, in my view, but the technology is there.

In addition to conservation, the most promising source of energy in the next century is solar power in all its forms. It is a tragedy in my view that the solar R&D has been choked off in the last eight years by an administration that seems to me to have virtually declared war on the sun. Someone told me that they even took that solar collector off of the White House, but I do not know that for sure.

Solar power is not a distant dream. There have been advances in the technology and if the Congress will simply provide the hundreds of millions of dollars per year rather than tens of millions, we can have photovoltaic cells that are economical by the turn of the century.

The conservation approach that I advocate is not doing without. Laws will make it happen, and I believe that the Congress should finally muster the strength to face the fact that we need to charge the energy companies the costs of the damage that they inflict on the environment. Pollution taxes must be a part of the solution because I think Senator Durenberger is right. The price is a regulator that regulates every day of the week and gets the job done.

Let me conclude by saying that I think we need some national goals in addition to all of these laws. The bill before you is an excellent piece of a mosaic that must be built. Let us establish a national goal of putting solar-powered electric cars on the road by the year 2000. No other single action could help more to clean up the air in the cities and in the atmosphere above while also reducing our dependence on imported oil. America is capable of achieving that goal if the Congress declares it and the Executive Branch implements it. I believe that most Americans expect the President and the Congress to join in a prudent course of making it happen.

My view from the State of Texas is that the American people are ready to face reality, but they must hear it from their leaders. Thank you.

Senator **Baucus**. Thank you very much, Mr. Freeman, for the very good testimony.

Dr. Chandler, you are next.

STATEMENT OF DR. WILLIAM CHANDLER, BATELLE-PACIFIC NORTHWEST LABORATORY, WASHINGTON, DC

Dr. **Chandler**. Thank you, Mr. Chairman.

The first thing that I want to say is congratulations, first for recognizing the severity of the problem of climatic change and the risks of global warming, and secondly for recognizing the importance of the role of energy efficiency in reducing that risk. I think that the chief significance of the Global Environmental Protection Act is that it recognizes that effective measures can be taken to reduce greenhouse gas emissions. There is a substantial body of technical and economic evidence to support this conclusion, and I would like to share some of those findings with you.

Many of the concerns and policies that are contained in S. 2666 are in common with those that were discussed in this study called "Energy Efficiency: A New Agenda," which was published by the American Council for an Energy Efficient Economy for which I was the coordinator. This project involved some 38 experts on energy efficiency from around the country, and our first recommendation and one of our highest priorities was to employ energy efficiency in a global effort to reduce the risk of climatic change by reducing carbon emissions.

In this project the most important conclusion was that energy efficiency does work. Over the last 15 years, between 1973 and 1987 at least, the United States was able to maintain energy consumption at a flat rate while increasing the output of goods and services by about 40 percent. In terms of rates, this was a two-and-a-half percent rate of energy efficiency improvement reduction of energy per unit of economic output. This rate climbed to over three percent in some years in the early eighties. It is a tremendous achievement, and I think it is maybe the most important contribution to environmental protection that we have made in the last 15 years.

Unfortunately, the momentum for energy efficiency may be dissipating. In the first half of this year energy consumption began increasing at an annual rate of about seven percent. You can translate that directly into carbon emissions and it means an additional 80 million tons at least of carbon being emitted by Americans each year. It is time to get back on track in bringing energy efficiency on line.

The technology remains to continue energy efficiency improvements. In fact, in most energy activities it is possible, I personally believe, to cut energy rates of consumption by half.

The importance of efficiency for the climate is shown on a graph on page 16 of my prepared testimony, which simply shows two scenarios. In one, global energy efficiency increases at a historical rate of say one percent per year, and in another, energy efficiency increases at a rate of two percent per year, slightly less than the U.S. achieved over the last 15-year period. The difference over the next three decades is the difference between we double or triple worldwide the annual emissions of carbon or whether we hold them constant. In fact, I think that it is possible based on available cost-effective technology to go beyond this two percent rate represented in this scenario and to actually achieve, using energy efficiency alone, the goal of the Toronto Conference on the Changing Atmosphere to cut global emissions by 20 percent by the year 2005. That would take very ambitious energy efficiency policies, and what this committee decides, the role it plays in leadership, will determine whether that can be the case.

In the agenda we covered a broad range of energy efficiency policies, and these are briefly listed on page 15 of my testimony. Of the 21 items, the first was to apply energy efficiency to protect the global environment through reducing carbon emissions. Let me just highlight the six categories which organize these policies.

The most important of these is doubling car and light truck fuel economy. The goals as I interpret them from S. 2666 are consistent with the recommendation that we made of achieving 45 mile-per-gallon fuel economy levels by the end of the century. Perhaps the difference between our approach and that taken in S. 2666 was to take a broader, more complimentary approach to policies and to go beyond the regulatory approach to include fuel taxes to make sure that there is an impetus on the part of consumers to demand more fuel efficient cars and incentives for manufacturers to produce those cars.

Third: Promoting least-cost utility services, with the idea here being to get utilities involved through applying incentives to acquire energy conservation resources. This differs a bit from the approach of regulation of appliances in that it may be a bit more cost effective.

The fourth item was enhancing industrial competitiveness through research on energy efficiency. It is critical that we get the industrial sector involved because some of the largest growth in energy use over the next 10 years could come in that sector.

Fifth, in making buildings more efficient, I think that the United States government needs to get its own house in order. There is lots of room for improvement in energy efficiency in Federal Buildings, and a strong leadership role could be played there.

Finally, coming back to the international arena, there is the need to help developing nations acquire the skills and technologies for energy efficiency. We can not solve the global climate problem without improving energy efficiency rates in developing countries. There is a large potential in developing countries and no one would benefit more from taking advantage of that potential than developing countries. It would increase their per capita incomes, save capital which could be diverted to other uses, and at the same time help to protect the global climate.

Again, let me simply reiterate my first statement and say that this is an important, landmark piece of legislation. Some of the items that I have suggested here perhaps belong in other jurisdictions, but I think that the leadership of this committee in presenting a unified view on energy and climate is going to be crucial. Thank you.

Senator BAUCUS. Thank you very much.

Our final witness is Dr. Mintzer.

STATEMENT OF DR. IRVING MINTZER, WORLD RESOURCES INSTITUTE, WASHINGTON, DC

Mr. MINTZER. Thank you, Mr. Chairman.

I recently returned from spending the last two weeks meeting with senior responsible officials in the Soviet Union discussing these issues. During this period, I also attended the 38th Annual Pugwash Conference of Global Security and Common Problems. I would like, in addition to my own testimony to enter into the record a declaration of one page produced at this meeting of 200 scientists, diplomats, and defense analysts from 38 countries, who explored the important linkages between the international environmental problems we are focusing on here today, the challenges of sustainable development for third-world countries, and the conventional and strategic military risks to national security.

Senator BAUCUS. Without objection, that will be included in the record of today's hearing.

[The material referred to follows:]

Dagomys Declaration of the Pugwash Council

Ensuring the Survival of Civilization

We live in an interdependent world of increasing risks. Thirty-three years ago, the Russell-Einstein Manifesto warned humanity that our survival is imperiled by the risk of nuclear war. The familiar challenges identified in that Manifesto and the 1982 Warsaw Declaration of Nobel Laureates remain as important as ever. But in the spirit of the Russell-Einstein Manifesto, we now call on all scientists to expand our concerns to a broader set of interrelated dangers: destruction of the environment on a global scale and denial of basic needs for a growing majority of humankind. Without reducing our commitment to arms reduction and war prevention, we must recognise that environmental degradation and large-scale impoverishment are already facts and can lead to massive catastrophe even if nuclear war is avoided.

The present inequitable international economic order confines many countries to the crushing cycle of poverty and induces them to use environmentally destructive industrial and agricultural practices. When coupled with worldwide population growth, and excessive production and profligate consumerism in the industrial nations, this is pushing the planet toward disaster.

Today's pattern of increasing energy use is a key link in a dangerous web of international environmental problems. Among these are global climate change, ozone depletion, acid deposition, and water pollution. These, combined with other potentially catastrophic effects, including deforestation, soil erosion, and mass extinction of species, reduce the earth's ability to support a growing population. The combined effect diminishes ecosystem functions in ways that will damage economies in the North and fatally undermine economies in the South.

These linked environmental problems affect all nations. They exacerbate international tensions and increase the risk of future conflicts through the impacts of sea-level rises, forced migrations, and persistent crop failures.

To survive, we must recognise that environmental degradation weakens the security of all. The challenge is to find ways to promote sustainable development of all regions in the world while reducing both military and ecological threats. Cooperation among nations, and effective organisations at the international, national, regional and local levels, are essential to maintain earth's life-support systems. Intense efforts must be made to foster a feeling of connectedness and cooperation and to correct economic injustices and promote trust.

The steps taken up to the present to halt environmental destruction have proved inadequate. Much stronger measures are required now. These include the development of alternative high-yield agricultural methods, while recognising the value of some traditional practices, in order to conserve scarce water and topsoil. They will also entail strict regulation of industry and land-use, and massive investment in environmentally sound practices, increased efficiency of resource use, deployment of renewable energy technologies, poverty reduction, and population planning. Education must promote a shift toward lifestyles compatible with the preservation of our life-support systems. Global use of fossil fuels must be reduced. The 1987 Montreal Protocol on Ozone Depletion must be strengthenend to eliminate the production and use of chlorofluorocarbons. International support for reforestation must be increased dramatically. In this way, the planet may move toward a new and stable balance in which nature can withstand the impacts of human civilisation.

Mr. MINTZER. Thank you.

The problems of global climate, stratospheric ozone depletion, and ground-level air pollution are intimately and inextricably linked to choices concerning U.S. energy policy. The choices of that energy policy made today in the United States will unavoidably affect the timing and the severity of all three of these linked problems. I want to commend the authors of this bill, S. 2666, and this committee for the conceptual advance incorporated into this bill, which is to recognize the intimate linkages between these three problems and to seek comprehensive solutions rather than to deal with them in a compartmentalized way.

The individual performance targets for energy using devices and energy supply technology included in S. 2666 are for the most part quite achievable with technologies currently available today or close to commercialization. We can indeed obtain the benefits that would result from 45 mile-per-gallon cars and from 50 percent efficient electric powerplants, as long as we recognize the joint benefits of coproducing heat and power. Unfortunately, however, these individual performance standards will not be enough to achieve the overall goals of S. 2666, which are to reduce aggregate emissions of CO_2 in the United States by something on the order of 50 percent.

In order to do this we must, in addition to improving the performance of individual machines and devices, improve the overall efficiency of our economy and stem the growth in aggregate energy demand. In order to accomplish that we must, as Senator Durenberger pointed out, use a variety of tools in order to allow States and local governments the flexibility that is necessary to meet area-specific emissions targets as well as technology-specific emissions targets.

I would like to point out a few of the specific thrusts that may be necessary in addition to the performance targets of S. 2666 in order to encourage this overall reduction. Critically important is the need to get the prices right. We need to encourage rational decision making in the market place by allowing our individual consumers and corporate leaders to see the full cost of energy supply and use in the price of fuels. There are several ways that we can do that.

One way may be to introduce a gas tax that might start at two cents per gallon and increase steadily at a rate of two cents per gallon per month over a four-year period, so that consumers could see a steady and predictable rise in the price of fuel and use that expectation to shape their choices of future purchases at the same time that manufacturers could shape their decisions about what models to bring to bear. In addition, we could ask utilities and other producers of carbon dioxide to pay a fee based on the amount of carbon that is in the fuel that is consumed. A similar user fee applied to CFC's could rapidly stimulate the introduction of safer, less depleting CFC's that would also reduce the risk of global climate change.

Another possible and potentially important thrust is a program that we at my institute have begun to think of as off-site mitigation. For example, asking the utility that wants to build a coal-burning power plant in Minnesota to lay aside an amount of funds that would support an annuity to plant the number of trees equivalent to withdraw the amount of CO_2 from the atmosphere that would be added by burning the coal in the power plant over its lifetime. As a result, there would be no net addition from the activities of that utility to the global warming problem.

Third, it is important for the U.S. Government to set an example about the usefulness and the feasibility of the energy efficiency technologies that have been discussed here today, in addition to supporting research and development. The U.S. Government in its various buildings, facilities, and laboratories could begin a demonstration program utilizing the best currently available American technology, demonstrating its cost-efficiency, reducing both the fuel costs of running the U.S. Government and its own insult to the global environment.

Finally, it is critically important that the U.S. Government support the prospects of sustainable development in third-world countries. We must encourage both our own bilateral aid agencies and those who use our funds in multilateral development assistance programs to support in an even-handed and wholehearted way the introduction of energy efficiency technologies into third-world countries.

In summary, I want to remind you that there are four essential elements of any solution strategy to the linked problems of ozone depletion, global warming, and acid rain. Those four elements are the following. First and most important is to increase the efficiency of energy used. Second is to eliminate the production and use of the most dangerous chloroflourocarbons. Third, through our aid and trade policies, to reduce the rates of tropical deforestation. Fourth and finally, to look for ways to shift the fuel mix, initially from carbon intensive fuels from coal to less carbon intensive fuels like natural gas, but ultimately to smokeless fuels, to an energy economy based, as David Freeman has pointed out, on solar energy technologies and other renewable sources that will not add substantially to the environmental burdens that we place on our children and grandchildren in order to enjoy the economic benefits that we hope to acquire today. Thank you.

Senator BAUCUS. Thank you very much, Dr. Mintzer.

I would like to do something a little bit different now. I would like to ask the panel jointly to address several different questions which I will soon pose, and in doing so, I would like to ask other members of the committee to join in at any time. I would like to try to get a discussion going here. My assumption is that using that method might help us to expose the truth a little more than the formal format would. Let's experiment and see what happens.

The questions I have are these. Assuming that global warming is a phenomenon that is having the adverse effects that many have testified—let's take that as a given. And assuming further that we want to reduce greenhouse gasses in America and the world—let's take that as a given. My first question is: what kinds of energy efficiencies seem to make the most sense? Let's talk about different ways to achieve energy efficiency with the result of less carbon dioxide emissions. The next question is: how do we achieve better conservation on the demand side, that is with more efficient homes and so forth in the area of consumption of energy? How do we achieve that result looking toward ultimately less carbon dioxide emission? Third, I want to ask about fuel-switching, as to what alternate fuels seem to be the most promising. Fourth, I want to ask about new potential technologies in new fuels, like Mr. Steinberg testified about. Fifth, I want to ask about the international ramifications of all this. That is: how do we encourage international cooperation? That gets into questions of competitiveness and how we can encourage other countries to also work toward these same goals.

Let's go back again to number one. The first question is: what kinds of energy efficiencies seem to have the most promise? Ms. Bleviss talked about a wide range, at least in the automotive area, but perhaps we can just categorize on the automotive side and also on the stationary side, what kind of technologies can we achieve energy efficiencies in the most promising ways?

Mr. TACHENY. That is really kind of a tough question. There are a lot of things being looked at to increase energy efficiency in power generation. I am sure that you have heard of a lot of them already, such as the co-generation concept where you try to utilize machinery in generating electricity so that you raise the efficiency above what is possible with a straight steam cycle where you are limited to the 30 percent area.

I personally think that the best chance we have is what we have termed the co-products plant, where you put together a couple of things that you want to do, such as an industrial process to make a product or to extract a product from coal and put that together with the need to generate electricity and you can achieve some substantial efficiency increases by that means.

Also, what we are concerned with really is the balance of CO_2, so if we can develop a process which maintains that balance, then we have worked toward achieving our goal. What I am talking about specifically is this. At Northern States Power Company we are burning RDF in our plants now. Here we are taking as a fuel a product that was very recently generated as a forest product turned into paper, utilized and now being used as a fuel. Therefore, we are returning CO_2 to the atmosphere which green plants in growing will utilize again and you have a cycle going that generates CO_2 in the burning process, but it also puts it into the atmosphere where it is reused by the growing plants and not adding more to it as you are when you dig coal out of the ground and burn it. I think that whole biomass area is something that has to be looked at and developed.

Senator STAFFORD. So that we in the committee can have a frame of reference as to who is producing CO_2—I note that in your statement you say that it is estimated that 28 percent of CO_2 emissions in the United States are from the production of electric power, transportation contributes 30 percent of the CO_2 emissions, and industry contributes about 24 percent. I read that because that gives us frame of reference as to who is using what and producing how much CO_2.

Senator BAUCUS. Let me ask if that is in agreement with the other members of the panel, because I heard somewhere that autos are responsible for up to 50 percent of the CO_2 emissions?

Ms. BLEVISS. The transportation sector accounts for about one-third.

Senator BAUCUS. Thank you.

Senator **Stafford**. That gives us on the committee a basis to work from there.

I notice that Dr. Chandler had his hand in the air, and if he is going to be next, I hope that he will comment on this. He said that the use of energy has increased by about seven percent in recent years.

Mr. **Chandler**. The first half of this year.

Senator **Stafford**. I wonder if you could tell the committee where that increase has occurred. Has it been in the production of electricity or in industry or in automobiles? I presume it is all three, but if we had some kind of a percentage here, that would also help us understand.

Mr. **Chandler**. The increase has been pretty much across the board throughout the economy.

Senator **Stafford**. Would it be safe to say 30 percent electricity, 30 percent transportation, and 30 percent industry, or something like that?

Mr. **Chandler**. I can find out exactly for you.

Senator **Stafford**. I was just trying to understand who is using more energy now and also where the CO_2 is coming from. I know that automobiles are being somewhat overpowered these days in this wild desire to drive as fast as you can with a great big engine.

Mr. **Chandler**. I was going to make the point about automobiles that they clearly are a priority. Each car in the United States emits about one ton of carbon, not CO_2, which is the unit this bill used, but each car emits about one ton of carbon per year. That is the same as the world average per citizen for all activities, so if the U.S. is going to deal with other people around the world in trying to cooperate to reduce carbon emissions, that is an area that we clearly will have to work on.

Senator **Stafford**. On that point, I noticed that Ms. Bleviss had a statement in her prepared text on page seven that caught my attention. It says:

> Volvo's engineers began their prototype project by setting minimum criteria for the LCP2000 to ensure that it was safe, non-polluting, comfortable, affordable, performed well, and could be manufactured easily. As a result, the vehicle—which has a fuel economy of 63 mpg city/81 mpg highway—can accelerate from 0 to 60 miles per hour in 11 seconds (against the American average of 13.1 seconds), and seats four to five persons.

Does such a car actually exist?

Ms. **Bleviss**. A prototype, yes.

Senator **Stafford**. A prototype does?

Ms. **Bleviss**. Yes.

Senator **Stafford**. That certainly would suggest that the modern motor vehicle could be much more efficient in fuel economy than any that we have at the present time outside of motorcycles. I own a motorcycle and it will go a long way, but my wife says that if I think I am going to get her to ride along with me, I'm crazy.

Senator **Baucus**. Ms. Bleviss, what are some of the promising automotive technologies that are reasonably cost-effective?

Ms. **Bleviss**. They span the spectrum. Unfortunately I can not list them all, but on the engine side of innovation, there have been new developments in both diesel control techniques, such as direct injection diesels, that if structured well could actually be less polluting, particularly for smaller cars. There are new developments with gasoline powered cars ranging from something known as two-stroke engines to something known as lean-burn engines. Toyota has been doing some work on the latter although General Motors was the first one to explore that principle. On transmissions, there is the continuously variable transmission. Subaru has already introduced such a transmission in Japan.

Aerodynamics is another area. Clearly the more aerodynamic your car is, the less power you have to expend in overcoming aerodynamic drag. The average drag coefficient of a car today is about 0.35 to 0.4, but Ford has designed a prototype car whose drag coefficient is 0.137, which is less than the drag coefficient of an F-15 military fighter jet. You can see where the potential is and you can track it in almost every single component in a car.

One of the things that would be useful for the members to look at are the "big bang for the buck" items. These are the much longer term research items, the endeavors that we probably are not going to see entering the possibility of production until the beginning of the twenty-first century. Some of these are items that are routinely dismissed by the automotive industry as not able to be done, and one such example of that is energy storage technology.

Our cars today run very inefficiently. They run in a state called part load, most of the time, which is the most inefficient mode. If you could get them to run at full load, store that energy, especially when they are decelerating or idling, and use that energy instead of the engine energy, in certain applications you are talking about very dramatic improvements. As far as I can see today, the only storage research that has continued in this country in the last eight years was at the University of Wisconsin for a couple of years and was supported by a Toyota affiliate. That was an area of endeavor which I think was quite promising. Some people are saying that there are potentially 100 percent improvements in urban fuel economy, yet no one is really looking at it at this technology.

Senator BAUCUS. Mr. Freeman?

Mr. FREEMAN. Ms. Bleviss spoke about transportation, and the other big sector is utilities. That is because most of the coal in this country is consumed in electric power plants. That automatically makes the utilities major contributors. As a matter of fact, the American utilities produce 7.5 percent of all the CO_2 in the world, so that we are major players here. It is well documented that there are lighting, motors, air conditioners and heating devices that are very much more efficient than what is being used. It is a question of the allocation of capital, and once and for all, this country has got to decide where its capital is going to be invested.

If we just take a look back we can learn something from our history. If the $100 billion in cost overruns and power plants that were not completed in the nuclear area had been invested in energy conservation, we might not even be holding this hearing today. Our energy consumption would be down tremendously. The people who invest capital in this country are the people that run companies like I did. They are the utilities, and they invest tremendous amounts of capital. It is my testimony that there must be a sterner direction to reallocate that capital into the conservation technologies. The average company is not in the conservation business. If the payout is not in a year or two, the consumer is not going to invest, but utilities have shown—they reach every home in America—and if there is a mandate that they can make their money only in conservation until they get it done, they will do it and they have shown that they can do it. These billions of dollars can be invested in new motors, in new lighting, in more efficient air conditioners. We are down there in Texas paying people to buy more efficient air conditioners, and it works. People are doing these things in an ad hoc way all over the country. My plea is to get to the jugular here, which is the allocation of capital in this country by the electric utilities and through a law, make sure that the capital is invested in conservation that is cost-effective and then and only then, allow new power plants to be built. We are not doing that in America today.

Senator CHAFEE. I have seen in our own area utility companies trying to avoid the cost of creating new capacity. They will write to the citizen and say, "We will come and cloak your boiler in a wrapping to save energy, free, with a bonus of some 75-watt light bulbs that only consume 68 watts of electricity." This is occurring, so I would like to follow up on what was said on the allocation of capital.

Congress is reluctant to tell the American industrial system that this is exactly the way they should go. We can create incentives to do it a certain way, but we find it difficult to pass a law that says you can not create new capacity. I guess my question to you, Mr. Freeman, is: you are down there in the heat wave section of the country. Have you been able to see the returns in providing people with a few extra dollars to help buy a more efficient air conditioner?

Mr. FREEMAN. Yes sir. That program is one that we are pursuing, and it works. We are building tens and tens of megawatts through conservation by a cash incentive and we have pulled the market so that the air conditioning manufacturers have steadily improved the efficiency of their product. Those systems work, and the people in New England are doing it too. My point is not that it is not being done anywhere; it is not being done everywhere and it is not being done across the board. You are correct, of course, in that you do not tell people how to spend their capital, but if there were a law on the books that no utility could build a new power plant unless its State regulatory authority certified that is was pursuing all of the conservation available, that would make a world of a difference.

Dr. MINTZER. I would like to add to that. One key element that would affect this capital allocation decision would be if utilities were able to rate-base their investments in conservation to an extent that they are not currently able to do today. Today if you build an electric power plant that burns coal, you can earn a fair and equitable rate of return on that capital investment. If you give an individual consumer a $50 rebate to buy a more efficient refrigerator, you do not earn any rate of return on that $50 rebate. Nonetheless, it displaces a substantial investment in capacity. A program of this type in California has reduced the need for new capacity quite substantially.

There are things that we can do, that you can do, that will make a significant input to the improvement of efficiency both on the supply side in the electricity sector and on the demand side.

Senator CHAFEE. One of the problems is, if we deter them from building new capacity they will keep the old capacity, which is the most polluting capacity. Are we then making progress toward eliminating these constant offenders with 40 year old plants?

Dr. MINTZER. It is not necessary in order to achieve the goal that you want to institute a sort of command and control economy that says you can not build a new plant. What you can encourage utility regulatory commissions to do, as has been done in a few of the States, is to offer preferential rates of return for either investing in plants and equipment that is more efficient on the supply side, replacing old generating equipment, even at a point more rapid than they had originally intended, or for making investments in conservation activities. By providing these differential rates of return we can take advantage of the market mechanism to encourage utility executives to make the kinds of decisions that David Freeman spoke about.

Senator STAFFORD. I would like to address a question to both Mr. Tacheny and Mr. Freeman, and I am going to preceed it by commenting that I think that maybe this committee might be here, today anyway, with possibly less sense of urgency than we are beginning to feel in connection with CO_2, because the rest of the world is out there and this Senator was just in China for two-and-a-half weeks and noted that there are a billion, 60 million people there now. There will be 16 million more a year from now, and they are all burning coal for every need of energy that they have. They are burning it to heat their houses, to cook their meals, and even to run part of their railroad. They are still building coal-fired steam engines for part of their rail system. They have three or four trillion tons of coal in reserve and they are going to keep on burning it because they have no other source and they lack the foreign exchange to buy much in the way of trying to control their stack gasses from industry.

This is a global problem. and we have to enlist somehow, the Chinese in helping to solve it, along with every other nation in the world that has any appreciable population. I think that America has to be a leader and operate through the United Nations Environmental Program and other international agreements as far as we can if we are going to succeed in controlling CO_2.

To come back to our own problems and a question, I agree with the statements made this morning that nuclear power is not a viable alternative in view of the reactions today to nuclear power on the part of the American public, but it seems to me that future nuclear power has to be an option at some point. My question is: would it be possible to make nuclear power much safer in the view of the public if the plants could be standardized and if we did not have different manufacturers responding to different requests to change virtually every plant that has been built today as they have gone along? Could nuclear plants be standardized and made safe enough that the public would be willing to accept them in place of having to breathe the contaminated atmosphere that we are facing today?

Senator BAUCUS. That is a very good question. I hear this point being made quite often, so I would be very interested in hearing the panel's response.

Mr. TACHENY. I have to say first of all that I am not an expert on nuclear power. However, to answer your question on the standardization of nuclear plants, I agree that would certainly help us to be able to overcome the public reaction and the fears that are there now. It has the disadvantage of focusing on one way of doing the job and not looking at many others that may have some advantages. I think that to revive and to allow nuclear plants to be built again, we would certainly have to go to some kind of standardization that people would recognize as being absolutely safe and would take the present fear out of nuclear power.

Senator STAFFORD. Would you care to comment on that, Mr. Freeman? You have had plenty of experience in this field.

Mr. FREEMAN. Yes sir, I would. I do not think that standardization alone will do the job. There are technical options for inherently safer nuclear plants. For example, the Swedish people have a design where you take the existing light water reactor and immerse it in a pool of borated water so that you have passive cooling. The danger of a meltdown then becomes virtually nil, although nothing is absolutely safe. I think that if we can bring the American public a brand new nuclear reactor design that we can say with a straight face has virtually no problem of meltdown and offer some sensible solution to the waste problem, which I frankly think is on-site storage for 50 years at the powerplant, not some hasty rush to find some place under the ground, then I believe that nuclear power can play an important role in our energy feature of the next century. It is going to take more than standardization. We have to standardize an inherently safer reactor. The reactors that we have now grew basically out of the naval submarine program and were not designed inherently for safety.

Senator BAUCUS. And you think that it is possible to standardize an inherently safer reactor?

Mr. FREEMAN. Yes sir, I know that it is possible, and it would not require the massive R&D effort that we put into nuclear before. These designs require the cost of one nuclear power plant to perfect. We just stopped the R&D program in nuclear, solar, and other things much too soon.

Senator BAUCUS. Anyone else want to express a view on nuclear?

Mr. STEINBERG. First of all, I think that Senator Stafford had a good point. I mean we are going to have oil and gas for maybe the next 50 years, but we have coal in the ground in maybe eight or nine major countries in the world, and it is in fact going to be a major source for the next several hundreds of years.

As a researcher as well as an engineer, I must warn the committee that any endeavor in terms of energy has its risks. There is no such thing as zero risk. In fact with a little tongue in cheek, I come from Long Island and we have Shoreham on Long Island. And I have been taking a survey on Long Island as far as generation of power is concerned, asking people, "Do you want to be irradiated or drowned?" It is a very severe kind of thing to say, but there are choices that we have to make in minimizing risk.

I agree with Mr. Freeman that the nuclear industry grew out of the military and that there are technical things that should have been done for the civilian nuclear power program. For example, in the nuclear waste program there are technologies of recycling and burning up long-term waste. The Japanese are beginning to do this and I think eventually that we are going to be doing this also because it is my opinion that it will take a long time before we agree to bury these wastes and my belief is that we will never want to bury it.

To address the last question about alternative fuels, we have to be careful about that in terms of either reducing imports or converting our coal. We have a major resource for coal. In terms of methanol, for example, we have to make sure that we do not generate more CO_2 in converting coal to methanol. There are two ways of technically dealing with carbon. You either remove the carbon before you use the coal or you remove it afterwards. I presented one possible option and I am a strong proponent of this research. I believe that the research should continue. There are options of combining coal with nuclear to reduce CO_2 as well. There are many technical possibilities for doing this, but each contains some risk. It is just a matter of minimizing that risk.

Senator BAUCUS. Dr. Mintzer?

Dr. MINTZER. I would like to respond to both ends of Senator Stafford's question, the part about nuclear first and then the part about China, because they both affect the timing and severity of the greenhouse problem. Although I believe that we in the United States have the engineering capability to develop the kind of reactor designs that Mr. Freeman has indicated, I do not know if they will indeed be safer than our current generation of machines. I am not at all persuaded that we could build nuclear plants fast enough to reduce the risk of global warming on a time horizon of interest to policy.

One recent analysis suggests that if one wanted to reduce the risk of global warming substantially by say half, you might need to build nuclear power plants, which now supply about five percent of our energy on a global basis, at a rate equivalent to opening one new plant per week between now and the year 2000. Such a rate of construction and of operation, I think, presents daunting challenges to social organization, even if we could mobilize the capital and physical resources to put the plants in place. The resulting economy of enriched nuclear fuel would at the same time rapidly increase our risks of other long-term environmental problems associated with both diversion by sub-national groups and diversion by national groups, who are quite interested in joining the nuclear club.

To turn to the question based on the People's Republic of China, I think you have put your finger on a key node in this problem. Although there are many opportunities to increase the efficiency of energy use both here and in developing countries—obviously one does not have to be rich to be wasteful—it is clear that as China and other third-world countries industrialize, their use of commercial fuels and of fossil fuels will grow, both on a per capita level and on an aggregate level. The challenge facing the U.S., I believe, is to see if we can extend our technological leadership to build a base for export of technologies that increase the efficiency of energy use that can help the Chinese to both sustain their plans for economic development and to minimize their need to implement their current plan to double their current level of coal use. The Chinese are the world's leading user of coal at about 900 million metric tons per year. They now plan to increase that to 1,500 million metric tons by the year 2000. We could rapidly increase the competitiveness of the U.S. economy, take advantage of our intellectual assets, and provide a global basis for an energy efficiency industry without resorting to risky exports of nuclear power.

Senator STAFFORD. Mr. Chairman, I think that deserves a comment, having just been there and having talked with people in the industry. I think the Chinese would like to improve their technology in burning coal and control stack gasses in their industry, but in order to afford the technology that the western world or the Japanese might be able to provide for them, they need trade with the western world in order to accumulate enough capital to buy the technology, which is very difficult for them when they are struggling to feed one billion, 60 million people every day.

Dr. MINTZER. It is going to require a broader view on the part of U.S. industry of participation in these ventures that include both joint venture and production in China with Chinese materials under profitable license to U.S. companies and strong emphasis on increasing the efficiency of energy use in China as much as the efficiency of energy supply. The Chinese now know that they have the least economically efficient use of coal of any of 100 countries that they surveyed in the world. It takes them twice as much coal as India to generate $1,000 of GNP. They want our help to improve their efficiency of coal use.

Senator STAFFORD. Thank you.

Senator BAUCUS. Does anyone else want to comment of the use of nuclear power options?

Dr. CHANDLER. I just want to underscore the importance of looking at the demand side, and I want to make a point about China and its efficiency of energy use. Not only does it take twice as much energy to produce a dollar of GNP in China as it does in the U.S., but you can see why that is the case if you look at their technology. It takes two to three times as much energy to make a ton of steel and twice as much energy to drive a truck in China. My point is that none of the supply technologies, whether nuclear, solar or whatever will work to supply the problem unless you get the maximum rate of energy efficiency out of the world economy that is available.

Senator BAUCUS. Earlier, Mr. Tacheny, you said that you did not think that the present technologies could satisfy the provisions in S. 2666, that is, that the 50 percent reduction of carbon dioxide by the year 2030 is just not achievable given present technology. Yet, Dr. Mintzer, I think I heard you say that you thought to the contrary, that even with present technology, the tough provisions of this bill can be met. I am trying to figure out where you disagree and why, in order to try to determine whether or not these technologies that currently exist can do the job. Could you indicate more precisely, Mr. Tacheny, why you think that the present technology is not sufficient to the task?

Mr. TACHENY. At Northern States Power Company, 50 percent of our energy comes from our coal-burning facilities. The other 50 percent comes from nuclear and hydro-electric. If we must reduce the CO_2 emissions from these coal-burning plants by that 50 percent, it would mean a tremendous cost in that—I am not really sure what the technologies are for removing CO_2 but what I understand is that it is by refrigeration processes to liquify it and then haul it somewhere else.

Senator BAUCUS. Dr. Mintzer, what are those technologies?

Dr. MINTZER. I think that we are talking about slightly different interpretations of the specifications in the bill. I did not mean to imply that all technologies can meet the standards of the bill both for 1995 and for 2000 and 2010.

It is my interpretation, first of all, that what the bill asks is a basis analysis on the usable energy output including both heat and power in order to achieve this efficiency improvement. Current coal and oil plants used in co-generation applications may be able to meet the 1990 and the 2000 standard, but it is unlikely that they will meet the 2010 standard. However, as a result of approximately $400 million per year investment in defense-oriented research to build highly efficient gas turbine engines, we are now on the verge of introducing advanced gas turbine devices. Spin-offs from this military engine program are called steam-injected gas turbines, which when used in co-generation applications could meet the standards set in S. 2666 even for 2010.

There are some important implications that one must recognize here. If one is to meet the 2010 standard in S. 2666, it will indeed as I view it, mean some shifts in the fuel mix from more carbon-intensive fuels like coal to less carbon-intensive fuels like natural gas. It is the fundamental chemical composition of these fuels in part that gives them an advantage in reaching the goals that are set forth in the bill. In addition, these new aircraft-derivative turbine technologies are 50 percent more efficient than conventional steam turbines, delivering efficiencies in their prototype units on the order of 45 or 46 percent. Even the integrated gasification combined cycle technology developed by a number of utilities can come close to reaching the 2010 goal. What it may mean is changes in our thinking about electric generation technology in parallel to the kinds of improvements that Mr. Chandler has been talking about on the in-use side of electricity applications.

Senator BAUCUS. Mr. Freeman?

Mr. FREEMAN. Mr. Chairman, maybe I could help bridge the gap. It strikes me that if the bill were supplemented with sufficient fees to assess the damages inflicted on the environment by the current technology and those fees were used to fund the research and development of these new technologies that we would have a margin of safety built into the process that would assure our achieving the goals. We cannot be sure which of these two gentlemen will prove to be correct if we simply expect the market place alone to provide the new technology. We have learned in this country that research and development just cannot be funded at a sufficient pace by private industry. Mr. Chairman, the world is not worth saving on a discounted cash flow basis.

Dr. **Mintzer**. There are two important issues here. One is whether you can, on an individual device basis, meet the standards that are the test in S. 2666. The other is the more important question raised by Mr. Freeman, which is whether our energy economy, our utilities taken as a whole, can meet this test. Will the market place drive the introduction of these technologies to a sufficient level that the aggregate reductions sought in S. 2666 will be accomplished? I would suggest to you that without policy intervention to change the pricing structure to provide the kind of incentives for research and development that Mr. Freeman is talking about that market penetration is unlikely to occur even though we may be able to achieve the device efficiencies that are identified on a unit basis in this bill.

Senator **Baucus**. Senator Stafford?

Senator **Stafford**. Mr. Chairman, while we have an expert here like Mr. Steinberg from MIT to help us understand another question better, let me ask this. As a layman I have understood that a principal customer for CO_2 has been plant life around the globe, which metabolizes carbon dioxide and exudes oxygen. I note in one of the testimonies however, that carbon dioxide could be pumped deep into the ocean and absorbed in the lower depths of the ocean where there isn't any, and that there is a lot of carbon dioxide in the surface of the sea. It is my understanding that much carbon dioxide is consumed by or at least enters the upper levels of the oceans. Would you be willing to very briefly tell us the process involved?

Mr. **Steinberg**. As far as removal of CO_2, I think that this is a well known technology. It is done in the making of fertilizers and removal of CO_2 for making ammonia. Costs are involved in that.

As far as the carbon cycle, which is what you are really talking about here, I am not an expert on that particularly, but from what I understand and from the studies generated by DOE the first thousand feet of the ocean is saturated and in equilibrium with the atmosphere, and they can account for at least 50 percent of the CO_2 that is anthropogenic that is produced by fossil fuels and remains in the atmosphere. There is some uncertainty as to where the other half goes.

Now, the statement about burying the CO_2 below the thermocline is the ocean. That is possible, however we made a study on this and showed that if you scrubbed all the stack gasses from the 300,000 electrical megawatts that we generate in this country and pumped it into the ocean, it would double the cost of power. If you are saving the world, that is not such a terrible thing. However, we do not really know what it will do to the ecology of the ocean. I refer to one thing which is what happened in Cameroon in South Africa, to that lake that turned over and burped out all the CO_2 and H_2S and asphyxiated a lot of people. Many oceanographers claim that this can not happen in the ocean levels, but I am not so sure, so I am not going to recommend that.

Senator **Baucus**. Let me ask a very basic question. Let's say that we move along the lines of this bill or something similar to it and let's say that we achieve the desired result, namely less carbon dioxide in the atmosphere and we tend to slow down and address the problem of global warming. As a consequence, this has been very costly and America is weaker. We are weaker economically because we spent all this money trying to reduce the CO_2 emissions. Is it worth the trade-off? Other countries are not doing very much to contribute to this massive problem and it is so costly to move to these different solutions. On the surface, I suspect that is a question that might pop up in the minds of some people and I would like to get your reaction to that.

Ms. BLEVISS. I would just like to address that in the context of what is proposed for vehicles, because this point has been repeatedly raised by the automotive industry.

Senator BAUCUS. We're not going to be able to sell cars and we'll lose jobs and so forth——

Ms. BLEVISS. That's right. And we are going to have to close down plants.

Senator BAUCUS. Sure.

Ms. BLEVISS. There are two other things that we need to consider in addition to the global warming issue, one of which is our energy security issue. The statistics cited much earlier today show that we are running pell mell into a renewed oil dependency. And combined with our reduced ability to produce our own oil, we are very likely to run into import levels in excess of what we have seen at the worst of our oil crises, perhaps as much as 11 or 12 million barrels per day by the next decade. The crux of that problem is the transportation sector which accounts for over 60 percent of our oil use, so we really have to factor in quite a lot of other considerations in addition to global warning concerns. Enhancing fuel economy could have major benefits for our energy security and in the absence of such enhancement, this country could be crippled economically as well.

In addition, looking at the nature of the domestic automobile industry, the industry itself is seeing untold competition compared to what it has ever seen before, and many people are worried about its long-term competitiveness. Amongst them are people who are worried about the strategies that are presently being undertaken by the industry, particularly the decision to concentrate on larger car lines as opposed to smaller car lines, and to deemphasize the fuel economy research. In the event of another oil crisis, many people are concerned as to whether we will have a domestic auto industry, because its ability to meet the kind of consumer demand that will reappear in such a case will be almost nil. Again I want to point out that fuel economy enhancement would provide a clear economic benefit that could accrue to a crucial American industry.

Senator BAUCUS. Any other reaction to that basic point that I made?

Dr. MINTZER. Whether or not the U.S. economy is weakened by attempts to reduce CO_2 emissions will depend strongly on what sort of policy strategies we choose to accomplish those reductions. If we choose to build expensive, complicated plumbing technologies that pipe all of the CO_2 out of out power plants into the bottom of the ocean, we are going to waste a lot of money. We will get weaker and it will look to us in retrospect like much of our initial development spending for foregone weapons systems. If however, we make those investments to reduce emissions by reducing the consumption of energy, we will find that it makes us stronger.

In this era, the cheapest, safest, fastest way to increase the level of energy services available to provide economic benefits is to increase the efficiency of energy use. In this room, for example, were we to substitute for the incandescent bulbs in the ceiling the kind of fluorescent bulbs that Mr. Stafford was talking about, we could deliver the same amount of light with only about 20 percent of the electricity used. By reducing the electricity used through this substitution of bulbs we could both reduce the amount of emissions that are associated with generating that electricity and reduce the cooling load, the heat that has to be removed by the building's air conditioning system, further reducing the emissions of these pollutants to the atmosphere.

Senator BAUCUS. What about super conductivity, is that a potential solution?

Dr. MINTZER. I think that it is a small part of the solution, much smaller than changing the light bulbs in commercial buildings, frankly.

Senator BAUCUS. Mr. Tacheny?

Mr. TACHENY. I would just agree that the greatest benefits are going to come from encouraging a lot of research into looking at better ways of doing things in all areas, and super conductivity is an area that we are looking at. My text mentions that we are looking at an energy storage facility that is pointed towards a super conductivity method.

None of these things will solve the problem in themselves. We need to combine all of them and I think that doing it on the research and development side and helping us to eliminate CO_2 from the stack gasses rather than trying to remove them after they have been generated or trying to find a better way to generate the energy in the first place so that you do not have the CO_2, is a win/win situation. We can then carry that technology to the world and say, "Look, this works and will help you also."

Senator STAFFORD. Mr. Chairman, I would like to agree with that. I think that whatever we do, we will not really succeed unless we can drag the rest of the world along with us.

Senator BAUCUS. On that point I would like to ask my final question. I think that is a central core part of the problem. Senator Stafford mentioned China, whose economy is deeply rooted in coal, and Dr. Mintzer reacted with the point that we can develop technologies that perhaps China can then use. Senator Stafford then responded that China has a difficulty generating the foreign exchange to pay for those technologies, to which someone else responded that we are the leader and should take the first steps and the other countries will follow suit. I tend to agree at a gut level with that, but I am wondering if someone can flesh that out a little bit. One idea I had was to perhaps put an amendment in this bill, some kind of a stick, that is some kind of penalty on imports or something that would not kick in for 10 years or so until after a country begins to take affirmative action to reduce CO_2 emissions. I am just trying to figure out some ways to help encourage this cooperation.

Ms. BLEVISS. My organization is one that works in developing countries, seeking to expedite energy efficiency there. And we have seen the problem that Senator Stafford has pointed to first hand.

Your gut reaction is a very viable reaction, Mr. Chairman. You can not minimize the impact that the United States has.

One of the problems that we have as Americans is asking a country to behave differently than we do——

Senator **Baucus**. Like parents and kids.

Ms. **Bleviss**. That's right. It is very hard to tell the Chinese to increase the efficiency of their economy when they do not seeing us making extremely aggressive efforts in this regard as well. Also, most of our assistance policies to these developing countries are not oriented around this area either. I would submit, at least with regard to the developing countries, that a carrot approach in that regard, rather than a stick, or at least the combination of the two is critical. We are not giving them the right information nor the right example at this point.

Senator **Baucus**. Mr. Freeman?

Mr. **Freeman**. I would like to reinforce what Ms. Bleviss said just there. The most important thing that we can do internationally is to assert some policy direction to the funds that the United States of America makes available through international lending institutions through our role in those banks. They are not pushing energy conservation as the number one investment opportunity.

I also think that we tend to forget in this country the contributions that we have made to world thinking. Multi-purpose river development with sensitivity to environmental concerns is something that America has made happen in the Tennessee Valley and throughout other parts of the country.

Just to speak of China, I happen to have made quite a study of the Chinese energy situation myself. They have the mightiest rivers in the world. They have tremendous opportunity for harnessing their water power to displace the future use of coal but they do not have the capital, and some of the financial minds of this country and the world need to take a hard look because China is the number three emitter of CO_2 and they do have mighty coal resources, but their water resources are immensely more economic and useful to the country for other purposes. There are many sites that could be developed without destroying the environment of China, but they just do not have the capital. I don't know that we can lend them the money, but maybe we can because those projects will pay off. They have got worlds of one- and two-cent electricity over there that will make the coal, the nuclear, and everything else unnecessary, and they know it but they cannot get the capital to make it happen. It is something that ought to be part of our thinking.

Senator **Baucus**. Dr. Mintzer?

Dr. **Mintzer**. I would like to emphasize what David Freeman said about shaping our aid policy and the use of our funds for multilateral development assistance agencies to reflect these priorities toward international environmental protection. The World Bank still is focused on increasing supply. They are underwriting 12 large new coal power plants in India and four new coal fields. India is the fourth largest coal user in the world and they want to be the third largest. The World Bank is underwriting the infrastructure to develop much of the Chinese coal expansion.

Senator **Baucus**. That is a good point. This committee took a step to try to remedy that not too long ago in trying to encourage the international lending institutions to develop in their statements——

Dr. **Mintzer**. It is a welcome move and it is one that has got to be reiterated, and it has got to be reflected in an urge from the U.S. Treasury Department to the bank to specifically incorporate consideration of the global warming, ozone depletion, and acid rain effects of the national energy strategies of these organizations that both the World Bank and the regional banks are promoting in our third-world partner countries.

Senator **Baucus**. Senator Graham has been a very active member of this committee in this and many other efforts.

We are happy to have you here, Senator.

Senator **Graham**. Thank you very much, Mr. Chairman. I congratulate you on holding what I am certain will be the beginning of a number of inquiries on this subject.

Some of the comments that were made earlier were reminiscent of some experiences that I have had in the efforts to protect the Florida Everglades, which is a very complicated system where unfortunately, the last 25 years is replete with examples of people thinking that they were doing positive and good things and ending up finding out later that they were misguided and actually exacerbated the problem. I am sensitive to the importance of the research function, not as it is sometimes accused of being, which is a means of delaying action, but as a predicate for intelligent action that will justify a sustained commitment.

I also am impressed with the importance of the international dimension of this, so I would like to ask a question in two parts. One is, without denigrating the intellectual power of our chairman and other members of the committee, which is awesome——

Senator **Baucus**. You're off to the right start.

Senator **Graham** [continuing]. We should reiterate that we are essentially lay people in this area and we need some guidance and direction on the issue of research. What should be the national research plan based on chronology? What do we need to know first? Where do we have the greatest opportunities for accelerating our understanding of this problem? Which research fits into what would be a potential action plan?

The second question is: how can we internationalize that research so that we are not in a parent/child relationship with the rest of the world but are emphasizing our common interests in this issue and our common vulnerability if we do not deal with it in an intelligent manner?

Dr. **Chandler**. I think that a first priority, in answer to your first question, is to stimulate cooperative research in industrial energy efficiency between the Federal Government and the companies themselves, particularly in those areas which improve productivity across the board, not just in energy efficiency but in labor productivity and capital productivity also, because those are the sort of items that capture industry's attention and they are the sort of things in which industry is going to want to invest. There is a large area for fertile research, not just in making current processes more efficient, but also in the development of wholly new processes so that we can move away from some of the energy intensive materials such as steel.

Dr. MINTZER. Let me address the second part of that question. I think that we are facing an unusual and fortuitous opportunity right now, in that building upon the success of the international ozone negotiations, the United States now has an opportunity to participate in the formulation of an inter-governmental mechanism to address the issue of climate change. If we are careful now and clever, we can help to structure this international effort so that our partners in the E.C., Japan, and the Soviet Union, as well as in developing countries engage with us in a two-pronged research effort. One prong would be directed to improving the quality of the science and the second would be to better understand the impacts and the policy options that are available to governments in response to global climate change in the future.

If we are careful now, we can build a mechanism which, as occurred in the latter stages of the ozone negotiations, brings together both the intellectual capability represented by industrial enterprises, by government agencies, and by the academic community, if we structure this effort so that leadership on the science side falls in the domain of the World Meteorological Organization and leadership on the policy side rests in the U.N. Environment Program. I believe that we stand a strong chance of replicating the success that we have seen in the last two years in the control of chlorofluorocarbons and the reduction of the risk of ozone depletion.

Mr. FREEMAN. Senator Graham, I think that the number one priority should be across-the-board support for greater efficiency in the various devices that we use, such as motors, lights, and air conditioners. But there are two very attractive specific technologies that I think could really make a big difference. One is photovoltaic cells, which are on the verge of becoming economical and would require less than a billion-dollar effort over five to seven years to become really commercial. That is a trillion-dollar market for American industry if we perfect it first. If not, the Japanese may be putting the photovoltaic cells—well, they will be selling us a car and a roof if we are not careful.

I think that our international competitiveness depends upon our being first to develop the photovoltaic cells, not to mention our survival on the planet. I do think that electric vehicles, powered by photovoltaic cells are on the verge of becoming economical, but Detroit will never make it happen. I have a letter in my files as the Chairman of the Tennessee Valley Authority from the President of General Motors promising me that we would have electric cars in every showroom by 1984. I got that letter in 1979, but as soon as the oil crunch was over, they cooled off on it. They are not going to perfect a competing line. It is going to take the Government of the United States of America making the decision that having put an electric car on the moon, we can put one on the road.

Senator BAUCUS. Ms. Bleviss, you have written a book on this subject. Do you agree with Mr. Freeman that photovoltaic cells can power cars?

Ms. BLEVISS. I think that is a much longer-term strategy. There have been a series of problems associated with electric vehicles. Solar electric power really is something that should be looked at in more detail, but another idea is hydrogen-powered cars, which deserve the same degree of intensity of research. The verdict is still out on them.

There have been very small solar-electric cars—I am sure you have probably seen the GM car that has been highly touted—but these would not provide the kinds of amenities that would make them attractive to consumers.

Senator BAUCUS. William Perry of the Chicago Bears probably could not ride too well in one of those.

Senator Graham?

Senator GRAHAM. I think that the suggestions that have been made are instructive of what might constitute the agenda. I am really asking more of a process question.

If this committee were to ask X saying, "We would like you to give us your recommendations within Y period of time as to what the national research effort should be, with its objective being to place us in the most advanced position to deal with this array of issues which fall under the title of greenhouse effect, and desirably, to do that in a way that would maximize international involvement and thus contribute to future cooperation in carrying out the imperatives of that research effort," who is the X, and what is the time period for Y?

Mr. STEINBERG. Sir, during the energy crisis, the Department of Energy has increased its technology research and development to improve efficiencies of electrical power generation and many other technologies, such as fuel cells, hydrogen cars, and so forth. That has passed by and therefore, we have less of an impetus. What I would say is to charge the Department of Energy in terms of recognizing that there is or there may be a carbon dioxide problem and begin to look at that. Right now as far as I know, most of the money has gone into understanding the problem, not necessarily solving the problem, whether it is mitigation or adaptation or some other means of dealing with the problem. It would seem to me that the Department of Energy is the place to go.

There are many incentives and disincentives and taxation policy statements that I can not address. I think that the other members of the panel have addressed them and that they are all valid. This could be done on an international scale because there are technology departments in all of these countries. Even in China, I believe that they are much aware of the environmental problems. What they can do about it because of their capital shortage and their infrastructure is a very difficult thing.

Senator GRAHAM. We have one recommendation that the Department of Energy is the X in that equation. Anyone have another candidate?

Dr. MINTZER. I think that what is necessary is a more broadly based interagency approach than can be managed singularly by the Department of Energy. I think there are a variety of aspects to this problem and there are currently several agencies at work on it. There is a study underway by the CBO; there have been two studies requested of the EPA.

From the policy analysis point of view, I would suggest to you that the Environmental Protection Agency perhaps working in conjunction with the Department of State on the international aspects is an important fulcrum on this problem. In looking at the technologies specific in the science aspects of the problem, I think that we have to bring to bear the combined resources of the agencies which are currently investing the greatest amount of funds in it. That is NASA, NOAA in the Department of Commerce, and the Department of Energy, but we really do need a two-track approach, an approach that both advances the science and systematically investigates the policy response options. For that, the Department of Energy by itself is not sufficient.

Mr. FREEMAN. Senator Graham, the Congress commissioned the Academy of Sciences, years and years ago. Perhaps a letter to them asking for their suggestions would be helpful.

Ms. BLEVISS. On the period of time, which was the second part of Senator Graham's question, one of the problems that those of us in the energy efficiency area are having is that people established an envelope of time—in five years, in ten years, we would solve our energy security problem.

Senator GRAHAM. Just for clarification, the Y that I am talking about is not to answer the problem but to know what the research scheme should be.

Ms. BLEVISS. I think that is an ongoing issue. Again, I would argue that one should call for an initial time period for preliminary recommendations, but we are going to do a lot of learning along the process, and if we do not have the ability to adapt our research as we go along, we are not going to solve the problem.

Mr. CHANDLER. I think that process should include the private sector as well.

Senator GRAHAM. One of the frustrations that is inherent in the legislative process is that these complicated issues do not come well packaged with easy to read labels. They come in very incremental, unexpected bits and pieces.

At our hearing two days ago we had an atmospheric scientist who criticized the Congress for failing to fund a relatively modest research effort which he said was critical to better understanding some of the science in this area. As one member of the Senate, who I guess stands indicted, I would plead ignorance if that is any defense. Nobody ever told me that we were doing this, and one of the advantages in having a research effort which could be broadly distributed so that people develop a sense of commitment to its realization is that then, when variance to that comes, when action which would be antithetical to the goals of the research were about to be taken, someone would sound the alarm and there would be the possibility of avoiding unintended negative departure.

Senator BAUCUS. I have no further questions. One final point is that now is the time for any of you to say anything if you have heard something that was outrageous or has gone under your skin a little bit before you leave. Is there any one final point that any of you want to make?

[No response.]

Senator BAUCUS. Thank you all very much for coming and participating today.

[Whereupon, at 12:50 p.m., the joint subcommittees adjourned, to reconvene at the call of the Chair.]

[Statements submitted for the record follow:]

Testimony of James R. Tacheny
Vice President of Combustion and Hydro Operations
Northern States Power Co.
Minneapolis, Minnesota

In the matter of "Global Environmental Protection
Act of 1988." Before the Subcommittee on Hazardous
Wastes and Toxic Substances and the Subcommittee
on Environmental Protection of the United States
Senate Committee on Environment and Public Works.
Dirksen Senate Office Building.
Sept. 16, 1988

Mr. Chairman, members of the committee: Thank you for the opportunity to appear today to state my company's views on what may be one of the gravest environmental problems society has faced. I wish my testimony offered specific solutions to the problem, but I do not believe that there is agreement on all of the questions, let alone the answers.

Northern States Power Co. (NSP) has been and will continue to be an environmental leader in the utility industry. We have taken steps voluntarily and in concert with regulatory bodies to ensure that we meet customer demand for electricity in an environmentally sound manner.

My testimony today will address NSP's views on global warming or what is commonly called the greenhouse effect, the utility industry's contribution to it, what we are doing about it and some recommendations that Congress and society should consider.

NSP and the utility industry certainly are aware of the increasing concern surrounding global warming. We recognize the growing scientific consensus that greenhouse gases will cause a global warming in the future. Scientists have documented increasing atmospheric concentrations of greenhouse gases, and recent work indicates average global temperatures may have increased by 0.5 degree C over the past century. If current trends in emissions continue, climate models show an increase in average global temperature of 1.5-4.5 degrees C within 50-100 years. This portends significant shifts in climate and world weather patterns.

However, many significant uncertainties remain. We do not yet understand the magnitude of the greenhouse effect, when the impacts will be felt, the severity of the problem or the potential impact on specific geographical regions of the world.

The current issue facing society, and especially you as policy makers, is that -- even given these uncertainties -- the **consequences** could be extremely large and far-reaching. It is for this reason that research efforts are dramatically increasing. And it is why the greenhouse effect is the subject of almost daily articles in the popular press.

What do we know now about the greenhouse effect? We know that carbon dioxide (CO2) is a major contributor to the greenhouse effect -- perhaps 50 percent. We know that whenever you burn a fossil fuel -- whether coal or oil in a utility boiler, or natural gas in a home, or gasoline in an automobile -- you generate CO2. Because utilities burn significant amounts of coal, oil and natural gas, we generate significant amounts of CO2. Incidentally, natural gas combustion produces about one-third less CO2 than coal because of its relatively high hydrogen content. It is estimated that 28 percent of CO2 emissions in the United States are from the production of electric power. Transportation contributes 30 percent of U.S. CO2 emissions, and industry contributes 24 percent.

However, let's remember that this is a global problem. United States electric power generation contributes only about 7.5 percent of world CO2 emissions. Assuming CO2 emissions are about half of the total greenhouse gas emissions, utilities in this country are responsible for less than 4 percent of the world total. In other words, even if United States utilities attempted to severely limit CO2 emissions, the effect on global warming would be negligible.

A second contributor to the greenhouse effect is nitrous oxide, N2O. While this is more commonly known as laughing gas, it is being treated as a very serious matter by researchers. However, the exact contribution of N2O to the greenhouse effect and the formation chemistry of this compound are poorly understood. The Electric Power Research Institute (EPRI) currently is sponsoring research to help resolve this uncertainty.

My statements are not intended to portray a "do-nothing" attitude by NSP, or the utility industry. We believe there are prudent, cost-effective and environmentally conscientious measures that can and will be taken now.

The first item is to increase the research effort currently under way, to more clearly define the many uncertainties I have mentioned.

NSP is committed to energy conservation. We have long advocated energy efficient standards for appliances and have given about $13.8 million in rebates to our residential and commercial customers for selecting energy-efficient appliances and equipment. In fact, many appliance dealers in our service territory only stock efficient appliances because our customers are demanding the rebates.

During the last four years, conservation and load-management has displaced about 190 megawatts (Mw) of capacity. We estimate that energy conservation on our system will displace the need for an additional 190 Mw by 1995.

Increased efficiency in generating units provides another means of equivalent emission reductions of greenhouse gases. One alternative to central generating plants burning fossil fuels at thermal efficiencies of about 35 percent would be co-product plants. Simply stated, two plants share the use of fossil fuels, thereby attaining overall thermal efficiencies of 50 to 90 percent or higher. For example, petrochemicals, metals or petroleum production from coal can be combined with generation of electric power, significantly reducing CO2 emissions. Future technologies such as fuel cells might also increase efficiencies.

Our available generating resources in 1987 were 7,500 Mw, from which we supplied 31 million megawatt-hours (Mwh) of energy for the year. NSP relies on coal, nuclear and hydro energy production from domestic resources, as well as hydro energy from Canada, to meet the energy requirements of our customers.

In 1987, about half of NSP energy came from coal. Nuclear power from NSP's plants at Monticello and Prairie Island provided 35 percent of NSP energy, and domestic and Canadian hydro sources averaged 5 and 10 percent respectively. We have signed an agreement with Manitoba Hydro for a year-round supply through 2005 for 500 Mw, or 3.3 million Mwh per year. Thus 50 percent of our energy is supplied by non-CO2 emitting sources.

There is no potential to significantly increase the amount of electricity we produce with water in our service territory. Other alternative energy sources, such as solar or wind generation, cannot provide enough electricity in the near future to alleviate the problem. Therefore, nuclear power is the only currently available technology in NSP's region to generate large amounts of electricity without contributing to the greenhouse effect.

While nuclear power is a proven technology, socially and politically we currently have no nuclear option in this country beyond using existing plants. Neither NSP nor any other utility I know of has any plans to build new nuclear power plants. I suggest that we re-visit the nuclear option. We should re-examine its social and political problems and decide whether we really want to abandon this option or make the necessary changes to make nuclear power viable again.

Another set of options that NSP is investigating now are systems to store electricity generated during off-peak, night and weekend hours. Storing energy to help meet peak demands would help us reduce CO2 emissions by increasing the role of our most efficient plants and maximizing the energy output of our nuclear plants.

Legislation presently under consideration, the "Global Environmental Protection Act of 1988," contains proposed CO2 emission limitations that, although admirable in intent, are not achievable, given present technology. Future policy and regulatory decisions must revolve around technologically responsible reductions in greenhouse gases.

Further, reduction in CO2 emissions by removal from stack gases is presently questionable and exceedingly cost- prohibitive. Even in the event that CO2 could be cost- effectively removed from stack gases, the technology associated with transporting and storing such immense quantities of CO2 is not fully developed. We believe that the utility industry should undertake development of new technologies allowing effective emission prevention rather than expensive removal.

Mr. Chairman, I stated at the outset that I don't have specific answers for the problem. But we can and must take actions today. We must significantly increase both industry and government research to better understand the greenhouse effect. We must look to energy conservation and develop new technologies to minimize the release of CO2. We also must determine whether we want to revive the nuclear power option. Finally, we should resist the temptation to impose emission limits when we do not know whether they are achievable or effective, given today's technologies.

Mr. Chairman, I hope my comments are useful as you and your colleagues consider a most serious issue. Again, I thank you for the opportunity to appear before you.

AN OPTION FOR THE COAL INDUSTRY IN DEALING WITH THE CARBON DIOXIDE GLOBAL GREENHOUSE EFFECT

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July 1988

ABSTRACT

A new technical option for the coal industry in dealing with the carbon dioxide greenhouse effect which has been devised. The option concerns a "hydrogen economy" based on coal. Traditionally the so-called "hydrogen economy" is based on nuclear and solar energy, electrolytically decomposing water into hydrogen and oxygen and using hydrogen as a fuel. However, one must remember that coal is not carbon; coal contains hydrogen. We have developed a very efficient process called HYDROCARB^{SM}, which effectively splits coal into carbon and hydrogen. The process has been described in detail. We are suggesting that coal refineries be built based on this technology. The original thrust of this process is to produce a clean, pure carbon fuel from coal for application in both mobile and stationary heat engines. A co-product of the process is a hydrogen-rich gas. If one is concerned about the greenhouse effect, then either all or part of the carbon can be withheld and only the hydrogen is used as fuel. If one desires to attain the ultimate, and eliminate all CO_2 emissions from coal, then all of the carbon can be stored and only the hydrogen used. The option is still open for utilizing the clean carbon, which would be placed in monitored retrievable storage, not unlike the strategic petroleum reserve (SPR). Should the greenhouse effect be found to be a myth in the future, the carbon would be taken out of storage and utilized as a clean fuel, the impurities having been previously removed. This concept can be valuable to the coal industry in response to the arguments of the anti-coal critics. In this regard, we believe this process is unique; no other process can make this claim. We are convinced that the HYDROCARB Process would be of substantial benefit, economically as well as environmentally, let alone psychologically, to the coal and fossil fuel industry.

THE PROBLEM

Increasing evidence is accumulating that is causing concern over the probability of a global carbon dioxide greenhouse effect. It is known that the concentration of CO_2 in the atmosphere at the turn of the century was 280 ppm; presently it is 345 ppm, an increase of 23%. This increase has resulted from human activity in burning increasing amounts of fossil fuel - coal, oil, gas - and from deforestation, the cutting down of forested areas. The effect is that the earth's surface is heated up, due to trapping the sun's reflected radiation from the earth by the CO_2 in the atmosphere. There are predictions that by the year 2050 the CO_2 concentration in the atmosphere could double, reaching over 600 ppm if there is continuing combustion of fossil fuel and deforestation: this would result in an average rise in temperature at the surface of the earth from 1.5°C to 4°C. Climate changes would occur in various regions of the earth and a melting of the polar icecaps and the glaciers would cause a significant rise in ocean levels. Since there are major areas of human habitation on coastal water ways, this could cause severe hardships. There is considerable research effort underway United States to ascertain and understand the carbon cycle, determining the first effects of CO_2 on the climate, ocean levels and the earth's ecology.

Carbon dioxide is not the only greenhouse gas. Methane and such polyatomic compounds as nitrous oxide and chlorofluorocarbons also have similar radiative effects. Perhaps with the exception of methane, these gases may be more easily dealt with than CO_2, because they are not major products of energy generation and thus would have less of an impact on human activity if they were banned. The processes involved in energy production, conversion, and utilization are thus at the root of the greenhouse problem.

ENERGY SOURCES AND ITS PROBLEMS

An interesting situation has developed concerning the production and utilization of energy. Basically, there are four forms of energy available to man on earth at present. These are (1) fossil energy (coal, oil and gas), (2) nuclear energy (fission now, and possibly fusion later), (3) geothermal energy, that is heat generated inside the earth, and (4) solar energy (which includes biomass (wood from trees and plants), agricultural and animal waste, direct solar radiation, solar photovoltaics, wind and hydropower). Wood and hydropower are categorized under solar energy because plants use solar energy through photosynthesis, and water accumulates in higher altitudes through solar evaporation and rainfall. The major sources of energy in the world today are fossil fuels in the industrialized nation and solar sources in the form of wood and biomass in the underdeveloped nations. Hydropower and nuclear energy come next, each probably supplying about 3% of the total energy. Some direct solar energy is used for heating water and geothermal energy supplies another smaller fraction of the total energy consumed.

The industrialized nations of the world use ten times more energy than the underdeveloped and developing nations of the world. In the former, fossil fuel provides the major fraction, followed by hydropower and nuclear energy. The potential resource of hydropower is very limited: much has been put into good use already and little remains undeveloped. The resource in fossil energy is vast especially for coal, which could last for thousands of years and the potential in nuclear fission energy is similar if it is greatly extended through breeder reactors, converting all the energy in uranium and thorium. Solar energy falling on the earth is much more than we presently use; however, the conversion of solar energy into convenient forms of energy such as heat, electricity and synthetic fuels is inefficient compared to conversion from coal and nuclear energy. Much effort is going into finding cheap and efficient ways to convert solar energy into alternate energy forms. This developmental effort includes energy farms, solar ponds, solar collectors, photovoltaics and wind. However, all of these technologies are at a very early stage of development.

A curious situation has arisen with respect to the greenhouse effect among the three major forms of energy; fossil, nuclear and solar. The proponents of nuclear energy say that they can avoid the greenhouse effect by eliminating the use of coal and utilizing nuclear energy based on uranium as fuel, which does not generate CO_2. The fossil energy industry says that nuclear energy is too dangerous to use because of the accidents that have occurred and that have a finite chance of occurring in the future. Such accidents would cause many cancer deaths and leave large areas of land useless due to contamination. The proponents of solar energy say that solar energy is benign and consistent with nature because the earth has been absorbing energy from the sun since its birth and that a CO_2 balance can be maintained in the atmosphere especially through the mechanism of photosynthesis in growing biomass for energy production. In response to the claims of those advocating solar energy, the proponents of coal and nuclear energy say that solar sources will be used increasingly by industrialized and developing nations, but because of its inherently low in tensity, solar radiation will be used only in limited and specialized ways and that the development process will be slow, inefficient and costly.

OPTIONS FOR THE COAL INDUSTRY

We have studied the problem of what the coal industry could do to mitigate or alleviate CO_2 greenhouse effect. Three definitive approaches were made by the Carbon Dioxide Research Division of the U.S. Department of Energy at Brookhaven National Laboratory (BNL). We first studied the physics, chemistry and biology relevant to the CO_2 molecule and how it can be removed, stored or transformed. Physically and chemically, CO_2 can be adsorbed on solids and absorbed in liquids. However, it is an acid gas and there are no known basic natural solid deposits that are sufficiently large to chemically absorb the vast amounts of CO_2 generated by humans. One possible storage area is the deep ocean. The surface of the ocean is saturated with atmospheric CO_2, but below several thousand feet there is no CO_2, and thus CO_2 can be pumped down into these depths to dissolve in the water, or, because liquid and solid CO_2 is heavier than water, it can sink as a liquid or a solid and remain on the ocean floor. Because of its vastness, the ocean could take up all the CO_2 generated from coal and the other lesser amounts of fossil oil and gas fuels. We can also attempt to think about separating and concentrating CO_2 directly from the atmosphere and pumping it into the ocean. However, it would be more energy-efficient to remove the CO_2 from the smoke stacks of coal-burning plants around the world and pump the concentrated CO_2 into the ocean. This concept was studied for the U.S. which showed that while it is technically feasible it would at least double the cost of power compared to what we pay today. Although this may not seem to be a severe economic penalty, there are two considerations that must be taken into account. First, to make a significant reduction in CO_2, the removal must be worldwide, and second, if the CO_2 is stored in the ocean, we do not know how it would affect the ocean's ecology. Although circulation of ocean bottom water with the top layers is very slow, eventually the extra CO_2 dissolved in the water could reach the surface. Furthermore, there is always volcanic activity in certain areas of the ocean floor which could disrupt the quiescent storage of CO_2 or that which is dissolved at lower depths. A small example of this effect occurred in Lake Camaroon in Africa last year when a volcano in a lake erupted and spewed out CO_2 and H_2S from the lake bottom causing up to 1800 deaths of humans and animals by asphyxiation. So ocean storage is not necessarily a benign long-term solution.

A search was made as to how we can utilize CO_2 as a material commodity. Among other things CO_2 is used today as a refrigerant, in producing fertilizer, and in plastics. One possible large market is to convert CO_2 to plastic construction materials. However, the fraction of the output of CO_2 from power plants that can be used is relatively small. For example, assuming all plastics can be made with CO_2 in increasing future U.S. markets, this use will amount to less than 10% of the CO_2 generated as carbon by the coal industry in the United States. One other possibility is to convert CO_2 to transportation fuels for the automotive industry. If this could be accomplished, it would reduce the use of fossil fuel by a significant amount, up to 30 or 40% in the United States. However, to accomplish this, it is necessary to chemically reduce or split the CO_2 molecule to carbon or carbon monoxide and oxygen. CO_2 is an extremely stable molecule requiring even more energy to disrupt than splitting water, H_2O, to its elements. Thus, only a non-fossil energy source can be considered for this purpose, such as nuclear or solar energy. Therefore, if we are going to use nuclear energy to assist fossil energy in reducing CO_2 for the transportation market, why not use nuclear energy directly for generating heat and electricity for the stationary power market and save the coal, oil and gas for transportation fuels? Putting the argument more directly, we could use nuclear energy for electrical power generation and leave the fossil fuel mainly in the ground. The coal industry then falls back on the argument that use of nuclear energy is not yet safe enough. So the utilization of CO_2 as a materials commodity is not a realistic solution either.

We can help the coal industry with the use of solar energy by planting trees and plants to absorb and convert, through photosynthesis, the CO_2 generated from coal-burning power plants. A brief study was made on this possibility, and it might be accomplished. We estimate that a tract of land 20 miles by 20 miles or approximately 400 square miles would be required to absorb the CO_2 from a 1000 MW(e) coal-burning electrical power plant for an average growing forest. For populated areas and poor agricultural areas, this may not be feasible because of the limited area of arable land available. However, the planting does not have to be adjacent to coal burning plants. The tropical zone of rain forests keeps a large fraction of the global CO_2 in balance by photosynthesis. Maintaining and increasing rain forests is a possible solution to keeping the CO_2 balance from increasing due to human activity. Infact, the cutting down of rain forests adds to the global increase in CO_2. There are questions about the long-term carbon balance in forests, in terms of sequestering increasing amounts of coal burning CO_2 emissions, because of forest decay, which itself releases CO_2 to the atmosphere after a period of time. Therefore, this wide concept eventually leads to generating energy from trees and plants on energy farms and eliminating fossil fuel use altogether. Indeed, a study on rapid growing trees on short rotation crop plantations showed that enough biomass could be supplied to replace fossil fuels for power generation worldwide. There appears to be enough arable land in the world to accomplish this.

Another technological approach is to improve the utilization of all our energy sources especially fossil fuels, and in particular, coal. A recently completed study showed that if new technologies known to the industrialized known to the industrialized world were applied on a world-wide basis, then by the year 2050, when the CO_2 concentration in the atmosphere is expected to double, the CO_2 concentration would be reduced by 60%, and would thus stabilize the concentration at about today's level. This reduction could be achieved by improved efficiencies of utilization and conversion of coal and other fossil fuels in end-use energy consuming devices. The technologies we have in mind include fuel cells magneto hydro dynamics (MHD), combined cycle power generation, and improved industrial, transportational, and residential energy conversion systems. Furthermore, an economic incentive and benefit would acrue by applying improved technologies. Less fuel would be used, and the savings in cost of fuel would pay for the capital investment needed for improved technology plants. The estimated rate of return on the investment could amount to 10% which is a reasonable one. The coal industry could easily support this approach.

ANOTHER OPTION FOR THE COAL INDUSTRY

Finally, the question can be asked: Is there a way of using coal for producing energy without generating CO_2? This may sound like an absurd question; humans have used coal and generated energy by combustion for centuries, and it is axiomatic that coal contains carbon, and when carbon burns with oxygen from the atmosphere, it generates heat and CO_2. How can one avoid this? We have found a way, but I must first describe a recently developed process for making a clean carbon fuel from coal.

The use of coal has its inconveniences. It is a solid, it contains ash and sulfur. When burned, it forms sulfur dioxide and nitrogen oxides which form acid gases, acid rain and smoke which contains fly ash. There is increasing pressure to restrict, through regulation, the emissions of particulate ash and acid gases which are perceived to injure humans and the environment. Coal deposits exist which have low ash and sulfur contents, but these coal seams are limited and more expensive to mine which significantly reduces the availability. Much effort is being expended by industrialized nations to develop coal-burning plants that will burn coal cleanly and reduce the impact on the environment. The removal of SO_x, NO_x and particulates from emissions have become developed technologies. However, the application of these technologies becomes a matter of increasing cost to the producer and to the consumer.

There is still another aspect to consider. Because of the vast coal resource which are orders of magnitude greater than the recognized resources of oil and gas, there was a movement to convert coal to liquid and hydrocarbon fuels which can directly substitute for present fuels in mobile heat engines. This resulted in a large synthetic fuel program in the United States about a decade ago, which since has been eliminated. Most of the petroleum in the world goes toward making gasoline and fuel oil for the transportation and heating-fuel market. Natural gas is mainly used for heating purposes, with increasing amounts now going into electrical power generation. Converting coal to liquid and gaseous hydrocarbon fuels always was at least twice as expensive as pumping oil and gas from wells and refining them to the conventional fuels used in our engines today. With present methods, the total emissions of CO_2 in producing synthetic substitute hydrocarbon fuels from coal would double and triple. Why is this? Coal contains a deficiency of hydrogen compared to petroleum fuels. The ratio of hydrogen to carbon (H/C) in coal is 0.8: in natural gas, H/C is 4: in gasoline, it is 2. Thus, to increase the H/C ratio in coal from 0.8 to 2 or more as a liquid or gaseous hydrocarbon fuel, the carbon in coal must be exchanged with hydrogen from water. There is no known natural source of hydrogen; it must be obtained from water. In making this exchange, coal reacts with water and oxygen forming carbon dioxide and hydrogen which then combines with additional carbon-containing material to form synthetic hydrocarbon fuels. The combined process puts out much larger amounts of CO_2 than when using coal directly in combustion. The synthetic fuel processes are expensive, and the extra expense is paid to obtain a more convenient gaseous or liquid fuel instead of less convenient solid coal. The processes are called coal gasification and coal liquefaction.

There is also a severe environmental problem. If vast amounts of coal are used to make gaseous and liquid hydrocarbon fuels, the CO_2 global greenhouse effect will be hastened. Because of the availability of low-cost natural gas ("the gas bubble") presently in the United States, there is an increasing movement towards converting large amounts of natural gas to liquid methanol. This process would increase the CO_2 emissions per unit energy by at least 50% compared to burning the methane directly. Of the three fossil fuels used directly in combustion, methane generates half the CO_2 compared to coal, while gasoline generates two-thirds that of coal. Therefore, converting methane to methanol adds to the CO_2 problem. Converting coal to methanol is even worse, because it would more than double the CO_2 emission compared to burning coal directly as well as gasoline for equal amounts of energy generated.

OUR RESOLUTION OF PROBLEM

We have devised an approach to the clean-coal problem for use in stationary power plants and in mobile heat engines. Coal consists of large organic molecules containing carbon, hydrogen, some oxygen and smaller amounts of sulfur and nitrogen. We developed a process for separating the hydrogen from the carbon in the coal, and disposing of the oxygen and the small amounts of sulfur and nitrogen as inert material. The process produces the cleanest form of carbon from the coal - called carbon black. Carbon black is practically 100% carbon, nothing else. It is presently and has for a long time been produced from residual oil and gas. Carbon black is used in inks and pigments; however, the largest consumer by far is the rubber tire industry. Carbon black is a vulcanizing agent. Almost every rubber tire made contains 10 to 20 pounds of carbon black. The carbon from coal process is called HYDROCARB™ and it is based on two well-known chemical reactions. The first reaction involves the hydrogenation of coal to form methane gas, and the second reaction thermally decomposes the methane to carbon black and hydrogen, part of which is recycled. In this cyclical process, there is no need for additional hydrogen, but rather hydrogen is produced as a co-product. The small amount of oxygen in the coal is removed either as water or as CO_2. Carbon black can be burned in a clean manner in stationary power plants or when mixed with water, gasoline, oil or even methanol. It can be pumped as a liquid mix which can be burned in diesel engines, turbines and even in internal combustion engines. Since it does not contain any ash, sulfur or nitrogen, it burns cleanly; the only product being CO_2. But the question can be asked: How does this solve the global greenhouse effect if it generates CO_2? First, the HYDROCARB Process is very efficient requiring a very small net amount of energy, much less than any coal gasification or liquefaction process. Thus, much less total CO_2 will be formed when burning carbon black than burning the inefficient coal-derived synthetic hydrocarbon fuels. Second, HYDROCARB produces a hydrogen-rich co-product gas. More impartiality, as mentioned earlier, the so-called pure "hydrogen economy" is based on generating hydrogen by splitting water either with nuclear or solar energy and promotes the use of hydrogen as the cleanest form of fuel. With the HYDROCARB Process, hydrogen also can be produced alone from fossil fuel, and the carbon formed can be placed in stőrage back in the coal mine. Thus we have a "hydrogen economy" based on coal. One might point out that we are paying a heavy penalty by not using a large fraction of the energy in the coal when only the hydrogen is used. Let us compare the thermal efficiency of generating hydrogen by converting nuclear energy to electricity then to electrolysis of water with that of HYDROCARB hydrogen from coal and not using the carbon. The efficiency of converting nuclear energy to hydrogen is 24% (30% uranium to electricity and 80% for electrolysis of water). The hydrogen energy from coal by the HYDROCARB Process has exactly the same efficiency, 24%. Furthermore, we have not destroyed the carbon fuel which can be put into "monitored retrievable storage" in the mines. Since there is still a probability that the greenhouse effect may not develop, then in the future the clean carbon could be taken out of storage and burnt to obtain energy in a clean manner that is environmentally acceptable since the pollutants were removed previously.

The process also allows utilization of part of the carbon produced, either in the form of carbon or as methane: it is not necessary to go all the way to hydrogen alone and totally eliminate the formation of carbon dioxide. The process is flexible enough so that the hydrogen to carbon ratio in the total fuel product-mix can be altered to any desired degree. For example, the co-product fuels can be adjusted so that the hydrogen to carbon ratio is equal to that in natural gas (4 to 1) or to gasoline (2 to 1). The more carbon that is consumed, the larger is the fraction of energy available from the original coal.

Underlying all of these options are the economic penalties, i.e., the capital and operating costs associated with implementing these technologies. Generally, all options for reducing CO_2 emissions will involve increasing capital investments and production costs beyond that which we pay today for energy. The axiom is well known, that costs are significant when attempting to protect the environment. However, some of the technology options costs less thatn others. The HYDROCARB Process to produce a clean hydrogen-rich fuel can be much less expensive than either nuclear or solar-photovoltaic hydrogen generation. HYDROCARB is at the lower end of the capital cost scale among all the other options mentioned. Thus, with the HYDROCARB Process, the coal industry need not take a defensive position to the accusations of the proponents of the so-called nuclear and solar benign clean fuel and can respond vigorously with an equally potent and superior technology for reducing CO_2 emissions.

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TESTIMONY BEFORE THE

SENATE SUBCOMMITTEE ON HAZARDOUS WASTE AND THE ENVIRONMENT

AND THE

SENATE SUBCOMMITTEE ON ENVIRONMENTAL PROTECTION

OF THE

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

On S. 2666

"The Global Environmental Protection Act of 1988"

Submitted by

Deborah Lynn Bleviss
Executive Director
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September 16, 1988

Messrs. Chairmen and Members of the Subcommittee, I would like to take this opportunity to thank you for inviting me to speak at this hearing on the Global Protection Act of 1988. I have been asked to speak on the prospects and potential for increased light vehicle fuel efficiency to meet the challenges of global climate change. But before I do so, I would like to commend the co-sponsors of S. 2666 for introducing the bill. Creating the political will to address such global problems as atmospheric warming and ozone depletion is critical to solving those problems, and S. 2666 is an important first step in that process.

In addressing the issue of the prospects and potential for increased light vehicle efficiency, I will be drawing from a study I undertook from 1985 through 1987, which sought to assess what progress was being made throughout the world on technological innovations that could improve fuel economy. That assessment was then combined with an analysis of the likelihood that such technologies would be introduced into production in as expeditious a manner as possible. Finally, conclusions were drawn about what could be done to speed fuel economy technology introduction. The study involved meeting with the major automotive companies of the U.S., Europe, and Japan, as well as some suppliers and independent researchers. The results of the study are published in a recently released book entitled THE NEW OIL CRISIS AND FUEL ECONOMY TECHNOLOGIES: PREPARING THE LIGHT TRANSPORTATION INDUSTRY FOR THE 1990S (Quorum Books, 1988).

While I will shortly go into more detail about the conclusions of the study, let me summarize them briefly. There is no shortage of technological options presently under development to improve fuel economy. In fact, some of the potential of technologies now under development can be seen in the bevy of fuel efficient prototype vehicles that have been brought forward in recent years, mainly by European companies. Generally speaking, most of these prototypes achieve at least 60 miles per gallon (mpg) in the city and at least 75 on the highway (see Table 1).

However, while the technological potential is great for fuel economy, there is no incentive at present to push automakers into introducing these technologies as rapidly as possible. Oil prices are very low; adjusted for inflation they are actually lower than the prices seen before the first oil price shock of 1973. In addition, competitive pressures do not seem to be adequately driving automaker interest in fuel economy. Finally, led by the United States, national governments have lost interest in pushing fuel economy.

In the following pages, I would like to examine in more detail the technological potential for fuel economy as well as the problems associated with meeting that potential. Then, I would like to turn specifically to S. 2666 and suggest ways in which the carbon dioxide goals set by that bill could be strengthened with supplementary programs that would increase the likelihood the industry would meet the goals.

The Technical Potential for Fuel Economy

In addressing the technical potential for fuel economy, it is appropriate to review where energy losses occur in today's modern light vehicle so as to be able to assess where the opportunities for efficiency improvements lie. Vehicle fuel is converted to useful work in the engine, where its combustion is used to turn the crankshaft. Seventy to eighty percent of the fuel's energy content is lost directly at this point to coolants, exhaust gases, convection and radiation. Much of this loss can be reduced, but thermodynamic laws dictate that generally over fifty percent of the energy content of a fuel cannot be recovered.[1]

Crankshaft energy is then transmitted to the vehicle's wheels through the transmission, with further losses occurring along the way. Today's manual transmissions, when driven optimally, have efficiencies of 90 to 95 percent with the increasingly popular automatic transmissions enjoying lesser efficiencies of 80 to 85 percent. Some crankshaft energy--about ten percent over a typical driving cycle--is also used to operate the vehicle's accessories, including its air conditioner and alternator.

Once power reaches a car's wheels, it must be used to overcome the aerodynamic drag of the vehicle (as determined by its drag coefficient, frontal area, and speed) and its rolling resistance (as determined by the friction of its tires, the road surface, and the vehicle's weight). In addition, energy is lost in braking. In urban driving, the fraction of energy dissipated by each of these functions is about equal--one-third each for overcoming aerodynamic drag, overtaking rolling resistance, and braking. On the highway, however, the fraction of energy used to overcome aerodynamic drag rises to more than 60 percent, while less than 10 percent is dissipated in braking.

Hence, the opportunities for reducing the fuel consumption of a vehicle lie in improving the efficiency of its engine and transmission; reducing its weight, aerodynamic drag, and rolling resistance; improving the efficiency of its accessories; and lessening the energy dissipation of braking.

New opportunities are now arising for improving the efficiency of engines. The advent of electronics and better sensor technology, for example, has enabled the development of ultra-lean-burn gasoline engines in which very lean air-fuel mixtures can be burned in low load conditions; Toyota has already developed such an engine for commercial use, finding a 20 percent improvement in fuel economy.[2] Similarly, the development of ceramics has facilitated the evolution of "adiabatic" or "low-heat-rejection" diesel engines which may eventually obviate the need for any engine coolants. If the waste energy of the exhaust gases from such engines can be effectively recovered, fuel efficiency improvements of 30 to 60 percent are possible.[3] Technology strides are even bringing back the stratified engine for re-evaluation. While such an engine is multifuel-capable and enjoys an efficiency comparable to a diesel, its widespread use has been hampered in the past by high emissions rates. Improved combustion techniques, however, in combination with better electronic controls promise to reinvigorate interest in this engine, possibly as a two-stroke, rather than conventional four-stroke, machine. In fact, Ford Motor Company has just signed a licensing agreement with the inventor of a high technology, two-stroke, stratified charge engine.[4]

Similar opportunities for efficiency improvements are arising with transmissions. Electronics advances have enabled better coordinative control of the transmission with the engine so as to maintain the latter in its more efficient full-load state as much as possible. Even more advanced has been the development of better conventional automatic transmissions. These are characterized by having more gears--hence maintaining the engine in full-load for a larger fraction of operations--or by lock-up clutches on all gears--hence reducing frictional losses of the torque converters used in such transmissions. Most advanced, however, are continuously variable transmissions or "CVTs" which have the potential to maintain the engine in full-load continually. CVTs are not new, but they have been dogged in the past by poor control methods, low power densities, and endurance problems. New electronics and materials advances have the promise to solve these difficulties.

Perhaps in no other arena will the technology revolution have a greater impact than with weight reduction, for a host of new materials have come forward with the desirable structural characteristics for use in a light vehicle. These range from ceramics to composite and polymer plastics to aluminum and magnesium alloys. The impact of these materials on weight reduction is substantial. One hundred lbs. of steel replaced by the appropriate amount (to yield the same degree of strength) of aluminum yields a 55 lb. reduction, replaced by a composite plastic a 65 lb. reduction, and replaced by magnesium a 75 lb. reduction.[5]

Of all the "new" materials, plastics has perhaps been the most widely publicized. Three automotive manufacturers--General Motors, Honda, and Renault--have already produced vehicles with body panels almost entirely composed of composite plastics. And work is proceeding furiously on developing chassis composed of plastics. Work is also progressing in applying other materials to light vehicles. Nissan has already commercialized turbocharger blades composed of ceramics; not only is the weight of the resulting turbocharger substantially reduced, but its performance characteristics are noticeably improved. Audi is working cooperatively with Alcoa Aluminum to produce an aluminum body for its 5000 series sedan that will achieve at least a ten percent overall weight reduction. And Volvo Car Company has developed a prototype vehicle in which magnesium accounts for an unheard-of seven percent of the vehicle's weight as compared with less than one percent for most of today's commercial vehicles.

Aerodynamics is another arena that has seen tremendous improvements in recent years. In the late 1970s, the average drag coefficient of American cars was about .48, with European vehicles achieving a slightly better .44.[6] In contrast, today the best drag efficient achieved by a production vehicle is .28.[7] And experimental vehicles are doing better still; Ford Motor Company has developed an experimental vehicle, the Probe V, with a drag coefficient of .137, besting that of an F-15 military jet aircraft.[8]

Improvements in tires are also being pursued vigorously. New tiremaking techniques developed by Goodyear and Bridgestone are delivering better rolling resistance while also improving steering precision, riding comfort, and braking performance. In addition, new materials for tires are being investigated, exemplified best by a small tire company in Kittsee, Austria, Polyair Maschinenbau GmbH, which has developed a tire made of liquid-injection-molded polyurethane. Tests conducted by the Venezuelan government have determined that cars with such tires use almost 10 percent less fuel.[9]

Light vehicle accessories are not being ignored either by the technology revolution. Energy demand by guzzling air conditioners is being reduced with better electronic control, the use of variable displacement compressors, and window glazings that decrease the amount of insolation into the vehicle. In addition, high efficiency alternators, electric power steering to replace energy-guzzling hydraulic versions, and low wattage "electroluminescent" interior lighting are being energetically sought. Finally, efforts are being launched to substitute solar energy for the engine as the source of power for accessories.

Perhaps the greatest challenge in improving the energy efficiency of light vehicles lies in reducing the energy loss associated with braking. Volkswagen was one of the first companies to address this issue by seeking to tap the unused engine energy associated with deceleration and idling. Its prototype Glider Automatic uses the engine to charge a flywheel storage device; in decelerating or idling conditions, when sufficient energy is stored within the flywheel, the engine is then turned off and the flywheel used to power the necessary accessories and restart the engine when power is next required.

A more advanced concept than this approach was under development for many years at the University of Wisconsin, with support from a Toyota-based company. That effort focused on an approach in which energy is stored whenever demand is less than what can be delivered at full-load conditions. Not only is this stored energy used instead of the engine in deceleration or idling, but it supplements the engine's power when additional boost is required. Finally, during braking a large fraction of the kinetic energy of the wheels is recaptured and stored. This energy storage system was installed in a 3,000 pound Pontiac Phoenix a couple of years ago and laboratory tests project the fuel efficiency of this vehicle will be improved some 50 percent.

The examples just listed are only a fraction of the research activity now ongoing. These are being pursued for reasons that extend well beyond their fuel economy benefits, for they offer a multiplicity of benefits. Plastics, for example, are attractive not only because they are lightweight, but because they can reduce assembly costs, and have a longer lifetime than their corrosion-prone steel counterparts. Similarly, CVTs are attractive to many not only because they are more fuel efficient, but because they offer a "jerk-free" ride compared to conventional automatic transmissions.

Inevitably, the question arises as to when these advanced technologies could reach commercialization. As already noted, some--such as plastic body panels--are already on production vehicles, albeit in limited numbers. Others, however, will require several more years of development. In truth, the rate at which these technologies will be introduced will depend heavily upon the aggressiveness of their research and development. Should an aggressive stance be taken, most of these technologies could probably be introduced into commercialization by the end of this century, with a few entering production in the early years of the twenty-first century (see Table 2).

But will these technologies really work in on-the-road vehicles? And what types of efficiency improvements could they produce in real vehicles? In the past, these questions have been difficult to answer until the technologies were commercially available. However, answers have become noticeably easier to come by lately because of the plethora of fuel efficient "prototype" vehicles mentioned earlier. Developed often at the instigation of the individual governments of the companies that have developed the vehicles, these prototypes combine low aerodynamic drag with improved engine and transmission designs and innovative substitution of lightweight materials. As already noted, with few exceptions, the vehicles enjoy city fuel economies in excess of 60 mpg and highway economies in excess of

75 mpg.

Moreover, even these innovative prototypes do not incorporate the most advanced fuel economy technologies now under development. For example, not one makes use of a ceramic engine. Similarly, no such vehicle utilizes advanced energy storage and regenerative braking systems. Hence, the fuel economy potential for light vehicles by the end of the century is probably even higher than reflected by these prototypes.

Not only has the development of fuel efficient vehicles been useful in demonstrating what efficiency technologies can produce, but it has also illustrated that other consumer amenities need not be sacrificed to achieve high efficiency levels. Perhaps the best example of this can be seen in the prototype developed by Volvo, the LCP 2000.

Volvo's engineers began their prototype project by setting minimum criteria for the LCP 2000 to ensure that it was safe, non-polluting, comfortable, affordable, performed well, and could be manufactured easily. As a result, the vehicle--which has a fuel economy of 63 mpg city/81 mpg highway--can accelerate from 0 to 60 miles per hour in 11 seconds (the average for the 1986 American fleet was 13.1 seconds), and comfortably seat four to five persons. In addition, it was designed to have a greater crashworthiness than is required today in the U.S. of production automobiles--American safety requirements being the toughest in the world--and to have emissions levels close to American requirements--these again being the most stringent worldwide. Finally, the car was engineered such that the increased costs of its materials and associated technologies could be offset by a streamlined assembly process, a side-benefit of the use of these materials. Hence, the LCP 2000's engineers estimate this vehicle could be manufactured at a cost comparable to today's cars of equivalent size.

Barriers to Expediting the Efficiency Transition

The news on the technical front, therefore, is quite hopeful. Not only are new technologies coming forward that expand the technological frontier for fuel economy, but they also are increasingly enabling fuel economy to be achieved while meeting--and in some cases improving upon--other consumer amenities. However, the rate at which these technologies will be brought into commercialization is subject to considerable uncertainty, for the "market" acting alone is not providing much incentive for commercialization at the present time.

First, low oil prices are discouraging both consumer and manufacturer interest in fuel economy. While consumers have truly lost their love affair with the large car--contrary to recent press and manufacturer reports--their tastes are still switching to more energy-intensive options. Demand for subcompacts has dropped in favor of the larger compacts. Within each size class, there is an increasing demand for engine performance. As a result, six-cylinder engines, and, to some extent, eight-cylinder engines are making a comeback. In addition, demand has grown for energy-guzzling options such as air conditioning, automatic transmissions, and power windows.

Exacerbating the problem of low oil prices is the fact that as the fuel economy of the national fleet increases, the economic impact made on a car purchaser of buying an even more efficient car diminishes. Trading in the 10 mpg car of a decade ago for a model that achieved 10 more mpg effectively meant doubling the owner's driving range, a noticeable change. However, trading in the 30 mpg car of today for one that achieves 10 more mpg only increases the driving range for the new car a third. Hence, regardless of the price of fuel, today's drivers are not receiving the same message on the virtues of fuel economy when they fuel up.

Of course, oil prices need not be the only market force in operation. Competitive pressures can spur the introduction of new technologies--many of which could well have fuel economy benefits--in order to gain market shares. And indeed it does look as if in the highly competitive Japanese and European markets some new fuel efficient technologies may move forward for this reason. But manufacturers do not bring forward new products unless they are fairly certain the demand for them will be there. Hence, to the degree they introduce fuel efficient technologies, these innovations are likely to be first introduced in smaller car lines, where polls have repeatedly shown that buyers are more interested in fuel economy. Perhaps the only technology to escape this stricture may be aerodynamic improvements in Europe. The high road speeds on that continent mean that consumers are interested in aerodynamics, not so much for its impact on fuel economy as for the benefit it offers in reducing wind-related noise.

While competitive pressures may have some role to play in bringing forward some fuel efficient technologies in Japan and Europe, similar activity is unlikely to occur in the U.S. As already noted, to the degree these technologies are introduced, they will probably concentrate in smaller cars. Yet, the decreased market share anticipated for domestic companies in the years ahead is expected to lead to a significant reduction of small car capacity by these companies in favor of larger car lines, where the competition is anticipated to be less intense. Hence, domestic companies will not have the very market segment where introduction of fuel efficient technologies would be most attractive.

Outside of market forces, governmental "push" in the fuel economy area could provide an incentive to bring fuel efficient technologies forward in an expeditious manner. Such a "push" is credited with much of the fuel economy improvement seen in the American fleet between 1975 and 1985. In 1975 and again in 1978, the U.S. Congress acted to establish a legislative framework for encouraging fuel economy. Perhaps most widely known, fuel economy standards were established (known as CAFE standards for Corporate Average Fuel Economy), which required the average fuel economy of new car fleets sold by individual manufacturers to rise to 27.5 mpg by 1985, up from an average of 14 mpg in 1975. In addition, the Department of Transportation was charged with setting similar standards for light trucks. Information programs were also established, including the creation of a fuel economy labeling program for new vehicles and the development of a comprehensive booklet on the fuel economies of all new vehicles offered for sale in the U.S. Finally, a gas guzzler tax was created that was to be assessed on the most fuel inefficient of vehicles sold in the U.S.

Not only did these programs have a significant effect on the improvements in fuel economy seen in this country, but they also prompted policymakers in Japan and most light vehicle-producing nations in Europe to establish similar programs seeking to encourage fuel economy.

Unfortunately, over the past seven years, the interest of the federal government in promoting fuel economy has weakened considerably. The CAFE standards have been rolled back for 1986, 1987, and 1988, and it appears very likely the 1989 standards will shortly be rolled back as well, even though all three major American automotive companies are likely to meet the original standard. Moreover, efforts have repeatedly been launched by the present administration to eliminate CAFE standards altogether. Needless to say, no thought has been given to increasing fuel economy standards.

In addition, liberal interpretation of the gas guzzler tax has enabled both Ford and General Motors to escape having to pay the tax even though several of their large car lines do qualify for the tax. Finally, information programs have been drastically cut back. At one time, 10 million copies of the fuel economy brochure, known as the Gas Mileage Guide were printed annually; today that level is closer to 3 million.

In the absence of American leadership in addressing fuel economy after 1985, the other major western light vehicle producing countries have also backed away from their fuel economy programs. Not one has established post-1985 fuel economy targets.

Increasing the Effectiveness of a CO_2 Control Program

I would now like to address the issue of fuel economy and its relationship to the Global Environmental Protection Act of 1988. Fuel economy improvements are the surest and shortest term means by which the carbon dioxide reduction levels for motor vehicles proposed in that bill can be achieved. There is a direct correlation between fuel economy improvement and CO_2 reduction: the doubling of fuel economy, for example, results in a halving of CO_2 emissions. As already noted, technologies are well under development that could dramatically improve light vehicle fuel economy.

In contrast, another proposed strategy for reducing CO_2 emissions, the substitution of alternative fuels for gasoline and diesel oil, is quite limited in the reductions that could be achieved, especially through the remainder of this decade. The most prominently mentioned alternative fuel today, methanol derived from natural gas, essentially emits as much CO_2 as gasoline. And methanol from coal would actually increase carbon dioxide emissions. Another frequently mentioned alternative fuel, compressed natural gas, does enjoy reduced CO_2 levels, but not in the amounts proposed by the bill. Moreover, the technology is not yet ready for extensive use of this fuel in light vehicles. Yet a third alternative fuel mentioned quite frequently is ethanol from biomass. Because this fuel is indeed renewable, its net contribution to carbon dioxide levels is negligible. But the fuel is extremely expensive. Moreover, in the short term, it could not be introduced on a sufficiently wide scale--due to the limited resource base from which it is produced--to significantly reduce carbon dioxide emission levels.

A third carbon dioxide control strategy occasionally mentioned with regard to motor vehicles is some type of "scrubber" that would chemically remove CO_2 from the tailpipe of a vehicle. Needless to say, this approach is essentially untested and many doubt that it could ever be effective.

Fuel economy therefore remains the predominant option for reducing carbon dioxide levels through the remainder of this century. But if fuel economy is to be pursued as the principal means of reducing CO_2 emissions from vehicles, there is considerable experience from the past decade on fuel economy policy--specifically on what has worked and what has not--that must be incorporated into a CO_2 control program in order for that program to have a chance of being successful.

The key aspects of such a program include:

- Set realizable goals for the automotive industry. With the apathy towards fuel economy exhibited by the present administration combined with today's low oil prices, the automotive industry in this country has fallen behind in developing efficient technologies. It will take these companies a while to be able to "come up to speed" on meeting new fuel economy goals. Moreover, the industry has other priorities as well as it deals with an increasingly competitive marketplace. Setting goals that are so high that they demand a major reallocation of funds which might otherwise have gone towards keeping the companies competitive would not do either the companies or the country much good. Setting fuel economy goals that seek to deliver new car fleets averaging 45 mpg and new light truck fleets averaging 35 mpg is probably the appropriate level of aggressiveness needed without unduly compromising other corporate needs.

● Set flexible goals for the automotive industry. There are two different ways that fuel economy can be achieved by the industry. One is to require automotive companies to increase the efficiency of every model line simultaneously. The other is to set a company-wide average efficiency improvement. Both achieve efficiency improvements, but the second is more flexible. A manufacturer can choose to concentrate on a few model lines first and then expand to others so long as the efficiency milestones for the fleet are met. This latter strategy is not only considerably less expensive for automotive companies, but it is also less risky. New technologies can be tried on a few models first--and improved if problems occur--with a lesser impact on overall sales than if those technologies had to be introduced over all model lines.

● Supplement the program with research and development. The study I conducted clearly showed that domestic manufacturers lag their competition in fuel economy research and development. At the same time, the needed R&D is not presently being done by the government, which has chosen to focus on very long term transportation conservation research such as gas turbines. Revamping the federal program to reflect the efficiency needs through the end of the century and beyond should actively be considered. Furthermore, the industry should fully participate in such a program, most likely on a cost-sharing basis to ensure that these companies maintain a stake in the success of the research.

● Provide incentives and disincentives to consumers. Automobile manufacturers are not operating in a vacuum. They produce vehicles that they perceive consumers will buy. And there is no doubt that consumers have reduced their demand for fuel efficiency significantly in recent years. Increasing fuel prices is part of the answer to reawakening consumer interest in fuel economy, but the previous discussion has shown the limitations associated with concentrating on fuel prices alone. A more effective way to reach consumers is probably through the price of the vehicle directly. As already noted, a gas guzzler tax does exist, but lax enforcement has enabled several manufacturers to avoid paying the tax. Moreover, the fuel economy threshold level below which the tax is assessed is no longer rising, even though the fuel economy of the American fleet is still rising. Hence, the message not to buy at the bottom end of the spectrum is being diluted. The development of a strengthened gas guzzler tax should actively be considered. At the same time, consumers are not being rewarded for buying highly efficient cars. Hence, the incentives to producers to manufacture vehicles at the high end of the efficiency spectrum are nil. Consideration should also be given to enacting a "gas sipper" rebate for the purchase of such cars.

- Strengthen information programs. As already noted, information programs have not fared well during this administration. But good information is required for consumers to make good decisions and automakers to adjust their products accordingly. Access by consumers to good, up-to-date information on the efficiencies of new cars and light trucks remains limited. And the accuracy of the federal fuel economy tests remains problematic. Solving these problems is critical to a good CO_2 reduction policy.

Conclusion

The co-sponsors of the "Global Environmental Protection Act of 1988" are to be commended on their foresight in addressing a critical environmental problem that to date has lacked the political will to try to solve. Improving the fuel economy of vehicles will be essential to meeting the carbon dioxide reduction goals for light vehicles established in that bill. The technological means are there to achieve high levels of fuel economy, but neither the market nor the government are at the moment providing any incentive to the automotive industry to introduce these technologies in as expeditious a manner as possible. While S. 2666 would reverse much of the government apathy on this issue, improvements could be made to the bill that would increase the chances the industry will seek to meet the prescribed CO_2 reductions. These include setting realizable and flexible goals, supporting research and development in this area, providing the appropriate consumer incentives and disincentives, and strengthening existing information programs.

1. Cole, D.E., and Johnson, J.H., Spark Ignition and Diesel Engines as Applied to Passenger Cars and Light Trucks, working paper prepared for the U.S. Congressional Office of Technology Assessment, December 4, 1979.

2. Kamo, Takashi, et. al., "Lean Mixture Sensor", Society of Automotive Engineers paper #850380, 1985.

3. Isuzu is working on a first generation ceramic engine, which it claims will improve fuel economy 30 percent (Automotive News, October 20, 1985). Recent analysis by Energy and Environmental Analysis, Inc. for the Office of Technology Assessment places the potential for fuel economy improvements from a truly adiabatic engine at 60 percent (Developments in the Fuel Economy of Light-Duty Highway Vehicles, June 1988).

4. Rowand, Roger, "The 2-Stroke", Automotive News, July 4, 1988, p.1.

5. Flemings, Merton C., et.al., Materials Substitution and Development for the Light Weight, Energy Efficient Automobile, prepared for the U.S. Congressional Office of Technology Assessment, February 8, 1980.

6. Buchheim, R., et.al., "Contribution of Aerodynamics to Fuel Economy Improvements in Future Passenger Cars", Proceedings of the First International Automotive Fuel Economy Research Conference, 1979, U.S. Department of Transportation, 1979.

7. This drag coefficient characterizes the Renault 25.

8. Probe V News Conference, October 28, 1985, Tokyo, Japan.

9. Marshall, Stuart, "First Test Report on the Revolutionary Plastic Tire", Popular Science, April 1983.

TABLE 1

High Fuel Economy Prototype Vehicles

Company	General Motors	British Leyland	Volkswagen	Volkswagen	Volvo	Renault	Renault	Peugeot	Peugeot	Ford	Toyota
Model	TPC (gasoline)	ECV-3 (gasoline)	Auto 2000 (diesel)	VW-E80 (diesel)	LCP 2000 (diesel)	EVE+ (diesel)	VESTA2 (gasoline)	VERA+ (diesel)	ECO 2000 (gasoline)-	— (diesel)	AXV (diesel)
Number of passengers	2	4-5	4-5	4	2-4	4-5	2-4	4-5	4	4-5	4-5
Aerodynamic Drag Coefficient	.31	.24-.25	.25	.35	.25-.28	.225	.186	.22	.21	.40	.26
Curb Weight (lb)	1040	1460	1716	1540	1555	1880	1047	1740	990	1875	1430-target
Maximum Power (hp)	38	72	53	51	52,88	50	27	50	28	40	56
Fuel Economy (mpg)	61 city 74 hwy	41 city 52 hwy	63 city 71 hwy	74 city 99 hwy	63 city 81 hwy	63 city 81 hwy	78 city 107 hwy	55 city 87 hwy	70 city 77 city	57 city 92 hwy	89 city 110 hwy
Innovative Features	Aluminum body and engine.	High use of aluminum and plastics.	DI with plastic and aluminum parts, flywheel stop-start.	Modified DI 3-cyl. Polo, flywheel stop-start, supercharger.	Hi magnesium use; 2 DI engines developed, 1 heat insulated.	Supercharged DI with stop-start.	High use of light material.	DI engine, high use of light material.	2-cylinder engine, high use of light material.	DI engine.	Weight is 15% plastic, 6% aluminum, has CVT & DI engine.
Development Status	Prototype complete, no production plans.	Prototype complete.	Prototype complete.	Ongoing research, possibility of production.	Prototype complete, adaptable to production.	Prototype complete.	Program completed.	Ongoing development.	Ongoing development.	Research.	Ongoing development.

TABLE 2

ESTIMATED DATES OF PRODUCTION-READINESS FOR ADVANCED LIGHT VEHICLE FUEL EFFICIENT TECHNOLOGIES

	1990		1995		2000
			[ENGINES]		
Variable Turbocharger		Torch Ignition	Solid Lubricants		
Pressure Wave Supercharger		1st Generation Ceramic Diesel		Advanced Ceramic Diesel	
Variable Valve Engine	Advanced Variable Engine Displacement			Oxygen Separating Engine	
	Dual Circuit Cooling				
	Electronically Controlled Cooling				
	Peak Pressure Ignition Sensor				
		"Clean" Stratified Charge			
Electronically Controlled IDI Diesel	"Clean" DI Diesel				
		"Clean" Ultra Lean Burn			
			[TRANSMISSIONS]		
	1st Generation All-Gear Lock-Up Clutch		2nd Generation All-Gear Lock-Up Clutch		
	Electronically Controlled Automatic Transmission With Torque Converter				
	Electronically Controlled Automatic Transmission With Synchromesh Clutches				
	Lubricated Belt CVT With Hydraulic Control		Electronically Controlled "Dry" Belt CVT		Beltless CVT

TABLE 2 (cont)

ESTIMATED DATES OF PRODUCTION-READINESS
FOR ADVANCED LIGHT VEHICLE FUEL EFFICIENT TECHNOLOGIES

1990	1995	2000
[MATERIALS]		
Composite Body Panels	Polymer Body Panels	
Composite Load-Bearing Parts	Composite Chassis	
	Fiber-Reinforced Plastic Engine Parts	
Increased HSLA Steel Use		
Aluminum Load-Bearing Parts	Aluminum Body	
Fiber-Reinforced Aluminum Engine Parts		
Magnesium "Interior" Parts	Magnesium Engine, Load-Bearing Parts, And Wheels	
Ceramic Liners And Turbocharger Blades		
[AERODYNAMICS]		
Drag Coefficients In The Middle ".20s"	Drag Coefficients In The Low ".20s"	
[TIRES]		
New "Dynamic" Tire-Making Processes	"Plastic" Tires	
[ACCESSORIES]		
Variable Displacement Air Conditioner		Solar Power For Accessories
Advanced Electronically Controlled Air Conditioner		
Laminated Reflecting Film Auto Glass		
"Smart" Alternator High Efficiency Alternator		
Variable Power Steering Electric Power Steering		
Electroluminescent Lighting		
[STOP-START/ENERGY STORAGE]		
Engine Stop-Start With Flywheel Storage		Complete Energy Storage

TESTIMONY OF S. DAVID FREEMAN

BEFORE THE SENATE ENVIRONMENT AND PUBLIC WORKS COMMITTEE

ON S.2666

SEPTEMBER 16, 1988

MR. CHAIRMAN AND MEMBERS OF THE COMMITTEE:

I APPRECIATE THE COMMITTEE'S INVITATION TO APPEAR BEFORE YOU TO TESTIFY ON S.2666.

I TESTIFY ON THE BASIS OF 20 YEARS OF INTENSIVE EXPERIENCE IN THESE INTERRELATED PROBLEMS OF ENERGY AND THE ENVIRONMENT. THIS EXPERIENCE INCLUDES DIRECTING A MAJOR STUDY OF THE PROBLEM IN THE EARLY 1970S SPONSORED BY THE FORD FOUNDATION THAT LAID OUT A BASIC ENERGY CONSERVATION STRATEGY FOR THE NATION. IT ALSO INCLUDES 7 YEARS (1977 TO 1984) AS CHAIRMAN AND A MANAGING DIRECTOR OF THE TENNESSEE VALLEY AUTHORITY, THE NATION'S LARGEST UTILITY. I AM PRESENTLY THE GENERAL MANAGER OF THE LOWER COLORADO RIVER AUTHORITY, A STATE-OWNED "LITTLE TVA" IN CENTRAL TEXAS.

MY TESTIMONY TODAY REFLECTS MY PERSONAL VIEWS BASED ON MY EXPERIENCE AND ARE NOT NECESSARILY THE VIEWS OF ANY ORGANIZATION WITH WHICH I HAVE BEEN OR I AM NOW ASSOCIATED.

I NOW RESIDE DEEP IN THE HEART OF TEXAS AND IT HAS BEEN SEVERAL YEARS SINCE I HAVE TESTIFIED BEFORE THE CONGRESS. I AM HERE TODAY BECAUSE I AM CONVINCED THAT OUR HIGH ENERGY CIVILIZATION IS ON THE ROAD TO DISASTER. I AM HERE TO SUPPORT THE EFFORTS OF THE SPONSORS OF S.2666 AND THIS COMMITTEE TO ENACT TIMELY LEGISLATION TO TURN US AWAY FROM THAT DISASTER.

I AM NOT A DOOMSDAYER BY NATURE AND I DO NOT BELIEVE THAT WE FACE A CHOICE BETWEEN AN UNLIVABLE CLIMATE AND FREEZING IN THE DARK. OUR QUALITY OF LIFE CAN BE SUSTAINED AND IMPROVED WITH A DRAMATICALLY LOWER LEVEL OF ENERGY CONSUMPTION AND FROM SOURCES THAT ARE FAR MORE COMPATIBLE WITH THE SURVIVAL OF THE PLANET.

THE KEY TO SUSTAINING AND IMPROVING THE QUALITY OF LIFE ON THIS EARTH IS TO FACE UP TO THE THREAT IN A TIMELY FASHION. OTHERWISE DRACONIAN MEASURES WILL BE REQUIRED FOR SURVIVAL. THE ISSUE BEFORE THIS COMMITTEE WAS PERHAPS BEST STATED BY EDMUND BURKE TWO CENTURIES AGO WHEN HE WROTE:

"THE PUBLIC INTEREST REQUIRES DOING TODAY THOSE THINGS THAT MEN OF INTELLIGENCE AND GOOD WILL WOULD WISH, FIVE OR TEN YEARS HENCE, HAD BEEN DONE."

MY CENTRAL POINT IS THAT WE DO NOT HAVE THE LUXURY OF 5 OR 10 MORE YEARS OF BUSINESS-AS-USUAL.

I HAVE BEEN A PARTICIPANT IN THE STRUGGLE TO RECONCILE ENVIRONMENTAL AND ENERGY POLICY IN THIS NATION IN GOVERNMENT AND AS A UTILITY EXECUTIVE. AND THERE ARE A FEW OBSERVATIONS THAT I

CAN MAKE WITH THE KNOWLEDGE OF SOMEONE WHO HAS BEEN ON THE FIRING LINE.

THE SCIENTIFIC EVIDENCE OF THE THREAT OF GLOBAL WARMING SEEMS OVERWHELMING TO ME AND MORE IMPORTANTLY TO THE VAST MAJORITY OF THE EXPERTS WITH SCIENTIFIC KNOWLEDGE. THE PLAIN TRUTH IS THAT THERE IS NO ABSOLUTE PROOF OF CLIMATIC CHANGE FROM THE BUILDUP OF CO2 SHORT OF SEEING THE COASTAL ZONES FLOODED AND THE HEARTLAND OF AMERICA RUINED. THE ISSUE IS NOT WHETHER THERE IS PROOF POSITIVE - THAT IS A SUICIDAL TEST - BUT WHETHER THERE IS SUFFICIENT EVIDENCE OF THE RISK OF CATASTROPHE TO SUGGEST THAT SOCIETY DARE NOT RUN THAT RISK. THAT EVIDENCE IS PLAIN ENOUGH FOR EVEN A LAYMAN TO UNDERSTAND AS WE FEEL THE HEAT THIS SUMMER.

YET THERE HAVE BEEN STATEMENTS IN RECENT WEEKS FROM LARGE COAL-BURNING UTILITY EXECUTIVES THAT CUTTING BACK ON THE ACCUMULATION OF CO2 IN THE ATMOSPHERE INVOLVES "CHANGING THE QUALITY OF LIFE OF EVERYONE IN THE WORLD." WELL, LET ME SAY AS A FORMER CHIEF EXECUTIVE OF AN ORGANIZATION THAT CONSUMED OVER 20 MILLION TONS OF COAL A YEAR THAT BURNING LOTS OF COAL IS HARDLY ESSENTIAL TO IMPROVING THE QUALITY OF LIFE IN AMERICA. I DARE SAY THAT WITH A REASONABLE TIMETABLE AND APPROPRIATE INVESTMENTS IN EDUCATION AND RE-TRAINING, PEOPLE THAT GO DOWN IN THE MINES AND DO THE HARD WORK IN THE COAL INDUSTRY WOULD MOSTLY AGREE THAT THEIR QUALITY OF LIFE COULD BE IMPROVED IN OTHER WORK.

LET US NOT EQUATE THE QUANTITY OF PROFITS FOR AN ENERGY COMPANY WITH THE QUALITY OF LIFE IN AMERICA. YES, MR. CHAIRMAN, THERE IS LIFE AFTER OIL AND LIFE AFTER COAL, AND IT IS TIME THAT AMERICA PUT ITS CREATIVE GENIUS TO WORK IN IMPROVING THE EFFICIENCY OF OUR USE OF ENERGY AND IN HARNESSING THE SUN IN ORDER TO OBTAIN THAT BETTER LIFE AND AVOID THE LIFE-THREATENING DANGERS THAT SEEM CLEARLY AHEAD.

AT EVERY STEP IN THE MARCH OF PROGRESS IN THIS COUNTRY THERE HAVE BEEN SPECIAL INTERESTS WHO HAVE TRIED TO BLOCK THE WAY. IF WE HAD LISTENED TO MY COLLEAGUES IN THE UTILITY INDUSTRY WE WOULD NOT HAVE SCRUBBERS ON POWER PLANTS NOR WOULD WE HAVE A COGENERATION INDUSTRY THAT IS USING FUEL MORE EFFICIENTLY AND PROVIDING TRULY BENEFICIAL COMPETITION. AND IF WE HAD LISTENED TO THE UTILITY AND AUTO EXECUTIVES, THE CONSERVATION IDEAS ADVANCED BY MYSELF AND OTHERS IN THE EARLY 1970S WOULD STILL BE GATHERING DUST ON THE LIBRARY SHELVES.

BUT, DESPITE THEIR NOISY REFRAIN OF "THERE'S NO PROBLEM AND IT COSTS TOO MUCH TO FIX IT," COMPANIES DO OBEY THE LAW. IF CONGRESS WILL ASSERT THE PUBLIC INTEREST BY ENACTING LEGISLATION IT WILL FIND THAT, JUST AS WITH SCRUBBERS AND JUST AS WITH CONSERVATION AND JUST AS WITH FUEL ECONOMY, IT CAN BE DONE AND DONE ECONOMICALLY.

MY EXPERIENCE AS A UTILITY EXECUTIVE AT TVA FROM 1977-84 IS LIVING PROOF OF THE FACT THAT UTILITIES CAN ACHIEVE CONSERVATION, AND DO IT CHEAPER THAN MORE PRODUCTION. TODAY UTILITIES ALL ACROSS AMERICA PURSUE CONSERVATION, BUT IN MOST CASES ONLY TO THE EXTENT THEY ARE REQUIRED TO DO SO. YET THE OPPORTUNITIES FOR SAVING ENERGY ARE LARGE, AS WE DEMONSTRATED AT TVA WHEN WE REACHED ONE MILLION HOMES AND BUILT THE POWER

EQUIVALENT OF A 1,000 MW NUCLEAR PLANT WITH CONSERVATION MEASURES.

AIR POLLUTION CAN BE REDUCED NOT ONLY BY CONSERVATION BUT BY INVESTMENTS THAT ARE ECONOMICALLY FEASIBLE AS WE DEMONSTRATED AT TVA BY INVESTING ONE BILLION DOLLARS TO CUT SULPHUR OXIDE EMISSIONS IN HALF, ELIMINATING ONE MILLION TONS PER YEAR. YET RATHER THAN COSTING CONSUMERS MONEY IT TURNED OUT THAT UPGRADING THE FOSSIL PLANTS AT TVA SAVED THE DAY. THIS IS TRUE BECAUSE TVA HAD TO RELY ON THE FOSSIL PLANTS (AND THEIR HYDROS) TO CARRY THEIR ENTIRE LOAD WHEN ALL THEIR NUCLEAR PLANTS WERE DOWN FOR THE PAST 2 YEARS.

WE NOW SHOULD SEE VERY CLEARLY THAT OUR HIGH-ENERGY CIVILIZATION'S LAVISH AND WASTEFUL USE OF PETROLEUM AND COAL IS CREATING A TRIPLE-BARRELED THREAT TO THE NATION AND THE PLANET AS A WHOLE. THE GLOBAL WARMING THREAT MUST BE ADDED TO THE OVER-DEPENDENCE ON IMPORTED OIL THAT POSES THE DANGER OF DEPRESSING THE AMERICAN ECONOMY FOR A THIRD TIME. AND WE MUST NOT FORGET THAT NUCLEAR POWER STILL POSES THE CLEAREST AND MOST PRESENT DANGER TO SURVIVAL ON EARTH.

A SINGLE PURPOSE, BLIND REACTION TO THE GLOBAL WARMING THREAT COULD THUS RESOLVE ONE CRUCIAL GLOBE-THREATENING PROBLEM ONLY AT THE EXPENSE OF EXACERBATING ANOTHER.

I AM OLD ENOUGH TO REMEMBER WHEN ATOMIC ENERGY WAS ADVANCED BY THE SIERRA CLUB AS A "CLEAN" ALTERNATIVE TO WESTERN DAMS. TODAY THE WHOLE WORLD KNOWS BETTER. THE PROLIFERATION OF NUCLEAR MATERIAL FROM POWER PLANTS IS A PRIME CONCERN, NOT TO MENTION THE DANGER OF MELTDOWNS AND THE CAVALIER DISPOSAL OF NUCLEAR WASTE THAT IS DANGEROUS FOR THOUSANDS OF YEARS.

I AM NOT OPPOSED TO NUCLEAR POWER BUT ITS VERY REAL DANGERS MUST BE OVERCOME IF WE ARE TO USE IT. AMERICA WOULD MAKE A TRAGIC MISTAKE IF WE RELAXED THE SAFETY STANDARDS AND PROCEDURAL SAFEGUARDS FOR LICENSING NUCLEAR PLANTS OF THE CURRENT DESIGNS. INCREASING THE RISK OF A NUCLEAR MELTDOWN IS NO WAY TO SAVE THE PLANET FROM AN UNLIVABLE CLIMATE.

THE FUNDAMENTAL RESPONSE TO THE GREENHOUSE EFFECT, TO THE ACID RAIN PROBLEM AND OTHER AIR QUALITY CONCERNS, TO THE THREAT TO OUR ECONOMY FROM OIL IMPORTS AND TO THE DANGERS ASSOCIATED WITH NUCLEAR POWER PRODUCTION ARE ALL ONE AND THE SAME. THEY ARE TO MAKE CONSERVATION THE CENTERPIECE OF OUR ENERGY AND ENVIRONMENTAL POLICY.

GOVERNMENT POLICIES NEED TO BE REVIEWED TO CONTINUE AND ACCELERATE THE MARCH OF PROGRESS THAT HAS TAKEN PLACE SINCE THE 1973-74 CRISIS. THE GROWTH OF AMERICA IN THE LAST 15 YEARS HAS BEEN ON THE BASIS OF CONSERVED ENERGY. WHAT WE NEED TO DO TO AVOID THE LITANY OF PROBLEMS I HAVE ITEMIZED IS TO ACCELERATE THE CONSERVATION APPROACH WHILE SIMULTANEOUSLY GREATLY EXPANDING THE RESEARCH AND DEVELOPMENT OF SOLAR ENERGY IN ALL OF ITS FORMS. AND, YES, RESEARCH AND DEVELOPMENT SHOULD INCLUDE NUCLEAR POWER; BUT WITH AN EMPHASIS ON SAFETY AND PREVENTING PROLIFERATION AS THE KEY CRITERIA.

THE MOST PROMISING SOURCE OF ENERGY IN THE NEXT CENTURY IS SOLAR POWER IN ALL OF ITS FORMS. AND IT IS A TRAGEDY

THAT THE FUNDING OF SOLAR R&D HAS BEEN CHOCKED OFF IN THE LAST EIGHT YEARS BY AN ADMINISTRATION THAT HAS VIRTUALLY DECLARED WAR ON THE SUN. THEY EVEN TOOK THE SOLAR COLLECTOR OFF THE ROOF OF THE WHITE HOUSE.

BUT LET US NOT BE DELUDED BY DREAMS OF ANY NEW SOURCE OF ENERGY THAT WILL GET US OUT OF THE FIX WE ARE IN. THE LAST 15 YEARS HAS SHOWN THAT WE CANNOT PRODUCE ENOUGH REALLY CLEAN ENERGY TO SATISFY OUR NEEDS. CONSERVATION IS THE FUNDAMENTAL ANSWER FOR A LONG TIME TO COME.

BY CONSERVATION LET ME MAKE CLEAR THAT I AM NOT TALKING ABOUT DOING WITHOUT. THE OPPORTUNITIES FOR IMPROVEMENTS IN ENERGY EFFICIENCY ARE NOT CONFINED TO THE MEASURES OF 10 YEARS AGO. EVEN WITHOUT MUCH GOVERNMENT FUNDING, THE TECHNOLOGY IS AVAILABLE TO DRIVE OUR CARS, HEAT, COOL AND LIGHT OUR BUILDINGS AND POWER OUR INDUSTRIES WITH MUCH LESS ENERGY PER UNIT OF SERVICE THAN IS REQUIRED TODAY.

WE CAN THUS ACHIEVE ECONOMIC GROWTH WITH STABLE OR DECLINING TOTAL CONSUMPTION OF ENERGY. BUT IT'S GOING TO TAKE SOME LAWS TO BE SURE THE CONSERVATION HAPPENS. THE REASON IS THAT MOST CONSUMERS LOOK ONLY AT FIRST COSTS AND DON'T INVEST IN FUEL EFFICIENCY THAT COSTS MORE INITIALLY BUT ACHIEVES FUEL SAVINGS WITH OVER A 5-YEAR PAYOFF. YET ENERGY PRODUCTION INVESTMENTS WHICH REQUIRE 20 OR MORE YEARS TO PAY OFF CONTINUE TO BE MADE BECAUSE THE ENERGY INDUSTRY HAS THE ACCESS TO CAPITAL AND ISN'T REQUIRED TO PAY FOR THE DAMAGE DONE TO THE ENVIRONMENT.

BUT THERE IS A GREATER DIMENSION TO CONSERVATION THAN UTILIZING HIGHLY EFFICIENT MOTORS, LIGHTBULBS, ETC. IT IS TO PROVIDE INCENTIVES FOR INDUSTRY TO MANUFACTURE PRODUCTS THAT LAST LONGER, THAT CAN BE RECYCLED AND TO STIMULATE GROWTH OF THE ECONOMY IN THE LESS ENERGY-INTENSIVE SERVICE SECTOR.

FURTHERMORE, WE CAN DRAMATICALLY REDUCE THE EMISSION OF CO2 IN THE FUTURE BY MODERNIZING OUR INDUSTRIES AND MORE IMPORTANTLY OUR TRANSPORTATION SYSTEM THROUGH SUBSTITUTING SOLAR POWERED ELECTRICITY FOR COAL AND PETROLEUM.

I SUPPORT S.2666, BUT IT IS ONLY ONE PIECE OF A PACKAGE OF ACTIONS THAT IS NEEDED. THE GLOBAL WARMING CONCERNS REQUIRE A BROAD REVIEW OF GOVERNMENTAL INVESTMENTS AT THE INTERNATIONAL, FEDERAL, STATE AND LOCAL LEVELS.

THIS IS NOT A TASK FOR REPORTS AND SPEECHES. LAWS AND EXECUTIVE INITIATIVES ARE REQUIRED. IN ADDITION TO THE REQUIREMENTS FOR GREATER FUEL EFFICIENCY IN NEW POWER PLANTS IN S.2666, I BELIEVE IT IS VITAL THAT UTILITIES SHOULD BE FORBIDDEN FROM BUILDING NEW POWER STATIONS UNLESS A STATE OR FEDERAL REGULATORY AGENCY CERTIFIES THAT THE UTILITY IS FUNDING ALL THE CONSERVATION PROGRAMS THAT ARE FEASIBLE AND STILL HAS A NEED FOR THE PLANT.

THE RECENT STATEMENT BY THE SECRETARY OF TRANSPORTATION THAT THE FUEL ECONOMY ACT IS "A DINOSAUR THAT SHOULD BE EXTINCT" BRINGS TO MIND THE URGENT NEED TO STRENGTHEN THAT LAW WHICH, BY THE WAY, NOT ONLY SAVED GASOLINE BUT SAVED DETROIT FROM EXTINCTION BY REQUIRING THEM TO IMPROVE FUEL EFFICIENCY AND THUS REMAIN COMPETITIVE. THE ACT NEEDS TO ESTABLISH A 50 TO 75 MPG

REQUIREMENT IN THE NEXT DECADE. NATIONAL SECURITY AND SURVIVAL INTERESTS REQUIRE IT. SOMEONE SHOULD TELL THE SECRETARY THAT THE DINOSAURS MAY BE EXTINCT BUT THEIR FOSSIL REMAINS ARE REAPING THEIR REVENGE AS WE BURN THEM.

THE PRINCIPAL OF REQUIRING POLLUTERS TO PAY WOULD REALLY HELP. A POLLUTION FEE ON THE FOSSIL FUELS TO FUND THE NECESSARY R&D WOULD BE VERY HELPFUL. IF WE REQUIRED THE FOSSIL FUELS TO PAY THE COST OF THE DAMAGE THEY INFLICT ON SOCIETY, SOLAR POWER MIGHT BEGIN TO LOOK LIKE A BARGAIN, AS NEWSWEEK POINTS OUT (SEPTEMBER 12, 1988, P. 67).

AMERICA NEEDS TO DECIDE ON A NATIONAL GOAL OF PUTTING LARGE NUMBERS OF SOLAR-POWERED ELECTRIC CARS ON THE ROAD BY THE YEAR 2000. NO OTHER SINGLE ACTION COULD DO MORE TO CLEAN UP THE AIR IN THE CITIES AND THE ATMOSPHERE ABOVE, WHILE AT THE SAME TIME DRAMATICALLY REDUCING THE DEPENDENCE ON IMPORTED OIL. THE TECHNOLOGY FOR BOTH THE ELECTRIC CAR AND ECONOMICAL SOLAR POWER ARE WITHIN REACH IF ONLY THEY HAD THE PRIORITY ON FEDERAL FUNDING AND COMMITMENT THEY DESERVE.

THE ELECTRIC CAR IS PERHAPS ONLY THE MOST OBVIOUS EXAMPLE OF HOW ELECTRIC POWER, IF IT COMES FROM THE SUN, COULD DRAMATICALLY REDUCE THE POLLUTION OF THE ENVIRONMENT. FAST ELECTRIC TRANSPORTATION BETWEEN CITIES, RAPID TRANSIT IN CITIES AND A HOST OF ULTRA-MODERN USES OF ELECTRICITY IN INDUSTRY COULD REPLACE MOST OF THE PETROLEUM AND COAL THAT IS USED.

TO MAKE ALL THIS HAPPEN WILL MAKE AMERICA BETTER, NOT WORSE. MORE EFFICIENT, NOT EXPENSIVE. MORE COMPETITIVE, NOT WASTEFUL.

I BELIEVE MOST AMERICANS EXPECT THE PRESIDENT AND THE CONGRESS TO JOIN IN ADOPTING THE PRUDENT COURSE OF PASSING LAWS AND TAKING EXECUTIVE ACTIONS TO CUT BACK THE ACCUMULATION OF CO2 IN THE ATMOSPHERE. FORTUNATELY THE SAME POLICIES TO DO THAT WILL ALSO PROVIDE AN ALTERNATIVE TO OVERDEPENDENCE ON IMPORTED OIL.

THE AMERICAN PEOPLE ARE NOW READY TO FACE REALITY. BUT THEY MUST HEAR IT FROM THEIR LEADERS.

AMERICA, AS THE WORLD'S LARGEST CO2 EMITTER, MUST TAKE THE LEAD IN A PLANET-WIDE EFFORT TO OVERCOME THE GLOBAL WARMING THREAT. IN THAT REGARD, THE RECENT FLOODING IN BANGLADESH BRINGS TO MIND THAT THE RIVERS OF THE WORLD CAN BE A SOURCE OF DESTRUCTION BUT THEY CAN ALSO BE HARNESSED TO PRODUCE VAST AMOUNTS OF HYDROPOWER. ONE OF THE TRULY IMPORTANT AMERICAN ACCOMPLISHMENTS BEGINNING WITH THE TVA HAS BEEN TO DEMONSTRATE MULTIPURPOSE RIVER DEVELOPMENT THAT CAN PROVIDE FLOOD CONTROL, ELECTRIC POWER AND OTHER BENEFITS.

THE RIVERS OF ASIA CONTAIN MANY SITES FOR BENEFICIAL MULTI-PURPOSE DEVELOPMENT TO PRODUCE VAST QUANTITIES OF HYDROPOWER TO DISPLACE THE HUGE VOLUMES OF FOSSIL FUELS THAT WILL OTHERWISE BE BURNED AND ADD TO THE ACCUMULATION OF CO2. YET HERE TOO WE MUST BE CAREFUL NOT TO SAVE THE CLIMATE AT THE EXPENSE OF RUINING THE GOOD EARTH. MULTI-PURPOSE DEVELOPMENT MUST BE SENSITIVE TO ENVIRONMENTAL CONCERNS AND ALL RIVERS NEED NOT BE DAMMED.

AMERICA MUST PUT THE GLOBAL WARMING THREAT AT THE TOP OF THE AGENDA OF THE INTERNATIONAL FINANCIAL COMMUNITY TO CHANNEL THE NECESSARY BILLIONS INTO THESE MULTI-PURPOSE RIVER DEVELOPMENTS. PERHAPS MORE IMPORTANT WOULD BE THE POLITICAL COMMITMENT BY THE AMERICAN GOVERNMENT TO "MAKE IT HAPPEN" WITH SENSITIVE REGARD FOR LOCAL ENVIRONMENTAL CONCERNS.

ALL OF US WANT TO IMPROVE OUR QUALITY OF LIFE AND NOT SEE IT DETERIORATE. GOVERNMENT SHOULD FACE UP TO DANGERS OF CONTINUING THE ENERGY JOYRIDE CAUSED BY OUR PREOCCUPATION WITH ENERGY-GUZZLING POSSESSIONS THAT WE QUICKLY THROW AWAY. IF IT DOES, I AM CONFIDENT THE AMERICAN PEOPLE WILL RESPOND VIGOROUSLY TO THE CHALLENGE.

THE ENERGY PROBLEM IS AN OPPORTUNITY FOR GREATNESS AND SERVICE. AS WE ASPIRE TO NEW CHALLENGES WE WILL NOT GIVE UP OUR MATERIAL COMFORTS; WE WILL STOP MAKING "TOO MUCH" THE PRIME OBJECTIVE OF OUR LIVES AND PERHAPS DEAL WITH THE PROBLEM OF THE PEOPLE ON EARTH THAT HAVE FAR TOO LITTLE.

YES, INDEED, THERE IS LIFE AFTER OIL AND COAL. IT CAN BE A BETTER LIFE IN WHICH THE AIR WE BREATHE IS CLEAN. THIS GENERATION OF AMERICANS CAN HAVE NO BETTER GOAL THAN SERVING FUTURE GENERATIONS OF AMERICANS BY HARNESSING THE SUN, AND BY STRESSING FUEL EFFICIENCY. THE MONEY WE SAVE IN OUR ENERGY BILLS CAN PROVIDE BILLIONS FOR EDUCATING OUR KIDS. IF WE'RE REALLY INTERESTED IN THE QUALITY OF LIFE WE'LL CONCENTRATE ON A POLICY FOR PRESERVING AMERICA, NOT POLLUTING IT.

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ENERGY POLICY STATEMENT

Adopted Unanimously by the Board of Directors

September 14, 1988

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ENVIRONMENTAL AND ENERGY STUDY INSTITUTE

ENERGY POLICY STATEMENT

EXECUTIVE SUMMARY

We believe that government must take decisive action to implement a new energy policy. The emergence of the global warming problem creates an imperative for action that cannot be ignored. The failure to act could well bring economic, environmental and human disaster previously unimagined. This is not a problem which can be addressed by an unfettered market since the problem of global warming is caused in large part by carbon dioxide produced from the burning of fossil fuels, whose prices do not reflect that damage. Therefore, we call for the next Administration and Congress to put energy policy at the highest level on the national and international agenda.

Moreover, there are other compelling problems that have persisted for years which also argue for a fundamental re-examination of U.S. energy policy. These problems include:

* The United States is engaged in a serious worldwide challenge to its competitiveness in which energy costs play an ever greater role, with U.S. costs per unit of output more than twice those of some of our competitors.

* The nation's current pattern of energy use is responsible for the unacceptably high levels of urban air pollution found in many areas of the country and for the acid rain and oxidants that are causing major crop and forest losses.

* Oil imports are rising and are projected to reach record levels. The growth of dependence upon oil from the Persian Gulf region raises energy security concerns. The cost of the military presence there adds billions of dollars to the direct costs of oil imports. In addition, the cost of oil imports is the single largest contributor to the country's record trade deficits.

While this country has apparently been willing to muddle through the problems of pollution, energy competitiveness and oil imports, the irreversibility of greenhouse warming does not allow that luxury. Several solutions are possible, but none is so appealing as improving energy efficiency, which uniquely responds to all of these concerns. And fortunately, the potential for increasing energy efficiency is immense. But achieving that potential will require the courage to raise the cost of using fuels that produce carbon dioxide.

BACKGROUND

Global Warming

Temperature increases of 1.5-4.5 degrees C by 2030 -- an unprecedented rate of warming -- are predicted if current trends in greenhouse gas emissions continue. Global warming could lead to climate instability that could disrupt precipitation and agricultural patterns, threaten the collapse of ecosystems, increase the probability and severity of weather extremes (e.g., droughts, hurricanes) and raise sea levels around the world.

Carbon dioxide is the single largest contributor to global warming and represents half of all greenhouse gas warming. The combustion of fossil fuels is responsible for about 80 percent of the carbon dioxide emissions with deforestation producing about 20 percent. Additional contributions to global warming arise from the atmospheric increase of nitrous oxide, methane and tropospheric ozone associated with fossil fuel use. To slow the rate of anticipated warming, less fossil fuel must be burned. In addition, chlorofluorocarbons (CFCs), which are utilized in such key energy applications as refrigeration, air conditioning and foam insulation, contribute another 15-20 percent of greenhouse gas warming.

Environmental Quality

The World Commission on Environment and Development in its report, Our Common Future, concluded that to have sustainable development, a sustainable environment also must be maintained.

In addition to global warming, the issues of acid rain and urban air pollution are direct consequences of the energy use pattern of the United States and the rest of the world. The energy used to fuel industrial growth and the country's increasing dependence on the automobile have resulted in spiralling urban smog and ozone levels, which are creating major human health problems.

It is now known that there are many ramifications of acid deposition and air pollution involving serious damage to forests, rivers and lakes, wildlife and crops. Furthermore, tropospheric ozone, produced by combustion of fossil fuels, is not only a major contributor to air pollution but a greenhouse gas as well. Other air pollutants from combustion increase methane and nitrous oxide which also contribute to global warming.

International Economic Competitiveness

The role of energy in international competitiveness is clear. The United States spent 10 percent of its GNP on energy costs in 1986. Japan spent 4 percent -- less than half the proportion of GNP spent by the United States. In 1986, this represented a difference of $200 billion -- which was, therefore, not available for investments elsewhere in the economy.

In addition, oil imports accounted for $44 billion (26 percent) of the nation's trade deficit in 1987. Projections by the Department of Energy indicate this could increase to $100 billion by 2000. World and domestic economic markets are greatly affected by the size of the U.S. trade deficit. We question how much foreign debt this nation can afford.

Competitiveness requires reducing the energy intensity of our economy -- in manufacturing, industrial processes, transportation and in the delivery of services such as heat and light. It also requires the development and marketing (internationally as well as domestically) of energy-efficient products and technologies. Otherwise, the United States will again be in the position of losing international and domestic market share.

Increased recognition of the environmental stresses being placed upon our planet -- many of which are derived from energy use -- and the need to act now will drive the development of new and improved technologies and products. To meet the demand in developing and other countries will be especially important, as they will be dependent upon such technologies. The United States should see this as an important market opportunity. Other nations such as Japan, West Germany and Sweden have already begun to anticipate the demands of such a new market.

Energy Security

With the collapse of world oil prices, oil imports have grown steadily and domestic production has fallen off. In 1987, oil imports constituted 35.5 percent of U.S. oil consumption. The United States has a mature petroleum industry with diminished reserves of inexpensive, easy-to-recover oil. The Middle East contains two-thirds of the free world's proven oil and natural gas reserves. The Department of Energy predicted in its 1987 energy security report that oil imports could account for more than half of U.S. consumption by the mid-1990s. This raises questions of vulnerability to potential supply disruption or, more likely, to sudden and substantial price hikes which, as was painfully learned in 1973 and 1979, can create economic chaos at home and abroad.

When the increased costs of military defenses in the Persian Gulf to protect the oil "pipeline" are included, imported oil is no longer "cheap."

Certainly, efforts to maintain diverse sources of supply and to continue the buildup of the Strategic Petroleum Reserve are important tools in helping reduce energy security concerns.

WHAT PATHS TO TAKE?

There are four categories of actions needed for a complete U.S. energy policy:

1. Increase energy efficiency, which we believe must be the first priority.

2. Stimulate the use of alternative energy sources and fuel switching.

3. Stop deforestation and promote reforestation.

4. Take leadership in developing international agreements to curtail greenhouse gas emissions from energy sources.

1. Increase Energy Efficiency

Energy efficiency can provide the largest, easiest, fastest and "least cost" contribution to help remedy the problems outlined earlier. Energy efficiency also buys us time--critical in enabling us to better develop alternative energy resources and slow carbon dioxide emissions while still burning fossil fuels.

The last 15 years of energy policy experience demonstrated that improving energy efficiency works. Efficiency improvements cut fuel use in power generation, transportation, industrial processes and in end-uses such as heating, cooling and lighting while delivering the same or improved level of services at substantial cost savings. While the United States uses little more energy today than it did in 1973, it produces 40 percent more goods and services. According to analyses done by the American Council for an Energy Efficient Economy, efficiency improvements have cut the nation's annual energy bill by $160 billion. However, the United States is still only half as efficient in its energy use as Japan, West Germany and Italy. And the progress this country has made has now stopped, and annual energy use has begun to climb again.

To regain these efficiency increases will require new government initiatives, particularly those that affect the price of fuels. Various policy options for improving energy efficiency are discussed below.

Tax Strategies: We have learned that price is the single most effective means through which to stimulate efficiency improvements. Therefore, in this time of relatively low energy prices, tax options must be courageously explored. Tax strategies should be examined to determine their ability to effect substantial reductions in energy use. At the same time, one must develop a plan that minimizes adverse impacts upon low-income households; the use of Social Security tax offsets is one such example.

Serious problems require serious solutions. One way to reduce the amount of fossil fuel burned and encourage the use of non- or low-emitting carbon fuels is a tax on carbon dioxide emissions. Therefore, we urge that a "carbon dioxide tax", as well as other mechanisms that would directly encourage emissions cuts, be explored.

We believe a phased-in gasoline tax (potentially approaching European levels) has the advantages of raising substantial revenue in an administratively simple way, affecting consumer behavior and creating less macroeconomic impact than alternative energy taxes. In addition, we urge consideration of an increased "gas guzzler" tax, as well as a "gas sipper" rebate for replacing an inefficient vehicle with the purchase of a fuel efficient vehicle.

Utilities: The utility sector offers great potential for efficiency improvements. Some utilities have done well in financing consumer efficiency and capturing the economic potential of efficiency improvements for residential, commercial and industrial customers. There is considerable "least cost utility planning" activity underway at the state regulatory level. Competitive bidding for energy conservation and diversified production is being tried in New England and a few other states. Efforts to design incentive rates of return for efficiency investments by utilities are underway in some states. Therefore, we recommend that the Public Utilities Regulatory Practices Act (PURPA) be amended to further encourage such activities at the state regulatory level.

Utilities (especially coal-burning facilities) also are the major contributor to acid rain and an important factor in greenhouse gas emissions (carbon dioxide and nitrous oxide). Efficiency strategies, both in production and consumption, are important in reducing all of these emissions. Yet most of the acid rain legislative proposals are focused on "scrubber" technologies which actually require more fuel to operate and, therefore, increase carbon dioxide emissions. We urge that acid rain proposals give priority to efficiency strategies, which not only reduce carbon dioxide emissions but also save dollars, to the full extent of their economic potential, including environmental costs. We also recommend that fuel switching from coal to gas and the substitution of non-greenhouse gas producing technologies be allowed to compete on the same basis as other control technologies.

Subsidies: Coal releases about twice as much carbon dioxide as natural gas, and petroleum is approximately halfway in between. Therefore, existing federal subsidies for energy production may be encouraging the development and use of fuels with high carbon dioxide emissions and discouraging the use of non- or low-carbon emitting fuels and energy efficiency strategies.

The Joint Committee on Taxation estimates that from 1989-1993, the exclusion of interest on state and local government industrial development bonds for energy production (largely coal-fired) facilities will result in tax expenditures of $800 million. Expensing of exploration and development and depletion costs for oil and gas and other fuels will result in $7 billion in tax expenditures over the next five years. Some sources estimate that subsidies to the nuclear industry run as high as $11 billion a year.

We recommend the removal of production subsidies that encourage the unwise use of fossil fuels and an end to the predominance of nuclear subsidies, which dwarf assistance to efficiency and renewable energy supply sources.

Transportation: Special attention should be paid to the transportation sector since it uses more than 63 percent of the oil consumed in the United States and is responsible for a large amount of pollution and greenhouse gas emissions (nitrous oxide, tropospheric ozone, methane and carbon dioxide). The amount of oil used for transportation is roughly equivalent to the total amount of oil produced domestically. Cars and light trucks are the largest users of oil and account for fully one-third of all U.S. oil use.

For this sector, as well as other sectors, we believe that complementary strategies will be necessary, working in tandem rather than one strategy working alone, to attain optimum energy efficiency improvements. Technologies are currently available which would allow fuel economy to be doubled, while retaining the current mix of vehicles. New fuel economy standards are an important tool in putting together an effective strategy. However, any new standards must be structured carefully to ensure fairness in the treatment of domestic versus foreign manufacturers. A combination of new standards with fuel and transportation sector taxes (which are discussed earlier) will result in more efficient use of petroleum-based fuels.

Energy Efficiency Research & Development: The development and implementation of efficient technologies should be accelerated. This will require increased federal support for efficiency R&D and demonstration. Such support should be provided through cost-sharing and cooperative planning with the private sector. There are exciting developments in transportation, electrical power generation, lighting and building climate control systems and in industrial process projects.

Energy efficiency and conservation R&D budgets were slashed by more than 50 percent during the 1980s, despite many successful projects which will ultimately yield billions of dollars worth of energy savings. Assistance with demonstration or commercialization of promising technologies is important because often the most innovation and willingness to take risks occurs in small companies which are not sufficiently capitalized to handle those costs. We urge that such assistance be provided in a careful, selective manner, recognizing that too often in the past "pork barrel" rationale determined where assistance was provided. We also recommend that greater efforts to improve technology transfer from the national laboratories to the private sector be encouraged. Moreover, efforts should be undertaken to make federal facilities a model of and testing ground for energy efficiency.

In summary, efficiency holds great potential. It is the priority strategy enunciated by the report "Developing Policies for Responding to Climatic Change" (prepared under the auspices of the World Meteorological Organization and the United Nations Environment Program) and the Toronto World Conference on the Changing Atmosphere. However, after making great strides during the decade following the oil price spirals of the 1970s, the latest Energy Information Administration statistics show the energy use per unit of economic output beginning to increase rather than continuing to decrease.

Improved energy efficiency is not the entire solution. But because enormous, cost-effective improvements are possible in every sector of the economy, and it makes sense to do them for many compelling reasons, we should move forward without delay. Expediting the implementation of energy efficiency technologies is the key way to reduce greenhouse emissions in the near-term and buys time for the longer-term transition to non-fossil fuels.

2. Stimulate the Use of Alternative Energy Sources and Fuel Switching

Solar and Other Renewable Energy Sources: Renewable energy sources are important contributors now and will be much more important to our energy mix in the longer-term. Solar, wind, geothermal, biomass, hydropower and other renewable sources produce no net greenhouse emissions and are technologies that should be supported, developed and implemented as expeditiously as possible.

The federal R&D budget for renewable energy was cut drastically in the 1980s. Tax credits for renewable energy were phased out. These actions slowed the development of renewable energy sources and greatly hindered their ability to compete.

Because of the importance of renewable energy sources to our energy future, we recommend a rejuvenated federal R&D program for renewables -- in partnership with the private sector through cost-sharing and cooperative planning arrangements. We support policies that will provide selective commercialization and implementation assistance to promising technologies. The United States has lost ground in many areas of renewable energy development (e.g., photovoltaics) to our trading competitors. This is a highly competitive area and hard work will be required to stay in the race. Government policies to enhance renewable energy development and implementation will pay off through worldwide marketing opportunities, the slowing of global warming and the reduction of harmful conventional emissions.

For example, with the help of federal R&D support, the installation costs for wind turbines have fallen by more than half since 1981 to $800-1200 per kilowatt -- becoming competitive with conventional power sources. Photovoltaic costs have decreased substantially to today's cost of $4-5 per watt -- making them competitive in remote locations -- but must get close to $1 per watt to compete in most markets. At the same time, the reliability and efficiency of renewable technologies has continued to increase. Federal support can play a critical role in accelerating these developments.

In addition, urban tree planting is a very cost-effective way to reduce air conditioning power loads and directly reduce carbon dioxide emissions. This should be encouraged, along with painting structures light colors to obtain optimal benefits.

Other Alternative Energy Sources: Alternative transportation fuels, such as methanol from natural gas, ethanol and hydrogen, are seen by many as important in reducing urban air pollution and demand for OPEC oil. However, we should be certain that the production and use of alternative fuels will not result in an increase in carbon dioxide emissions above that of the displaced fuel.

While nuclear power does not generate greenhouse gas emissions, it would take a completely new design to compete economically and gain public and investor support. Therefore, we do not believe that it can make any substantial additional contribution to our energy mix in the near future when compared to other available efficiency and renewable energy options.

Fuel Switching: Because there are large differences among fossil fuels in the amount of carbon dioxide released when they are burned, we recommend that legislative and regulatory barriers to fuel switching be removed. The Clean Air Act should be amended to ensure that efforts to meet air quality standards do not exacerbate the greenhouse problem or stand in the way of innovation. Since natural gas produces only half as much carbon dioxide as coal, fuel switching or co-burning of natural gas with coal can significantly reduce greenhouse emissions as well as other conventional pollutants.

3. Stop Deforestation and Promote Reforestation

The forests of the world are vast "sinks" for carbon dioxide. Deforestation has increased as a result of economic development projects and growing demand for firewood in over-populated areas, particularly in developing countries. Twenty percent of the world's annual carbon dioxide emissions result from deforestation.

The halting of deforestation and promotion of reforestation are important strategies for helping slow the rate of global climate change, as well as providing an environment that can support sustainable development. Moreover, any reductions in deforestation play a critical role in helping preserve biological diversity. We, therefore, urge the adoption of domestic and international policies which seek to stop deforestation and encourage reforestation.

For example, it is possible to help offset the carbon dioxide emissions of a coal plant with a reforestation program. Costs can be held to modest levels by utilizing debt-for-nature swaps. Reforestation is a critical mitigation strategy which helps buy time since countries will not be able to stop burning fossil fuels in the short-term.

4. Take the Leadership in Developing International Initiatives to Reduce Global Warming

The United States cannot solve these energy and environmental problems by itself. Global strategies developed and faithfully implemented by both industrialized and developing nations are required. Strong leadership domestically and internationally by the United States is critical if effective global strategies to limit greenhouse emissions are to be developed.

In coming years, much of the increase in greenhouse gas emissions will come from increased industrialization and agricultural production in developing countries. Therefore, we urge that energy efficiency and renewable energy strategies become an important component of U.S. bilateral and multilateral foreign assistance programs. The United States should work with other donor nations to ensure that their programs also share this priority. Efforts to improve technology transfer to developing nations should be a priority. This is critical if significant steps are to be taken to slow global warming.

Much of the energy currently used in the developing world is used very inefficiently. At the same time, many applications of solar and other renewable energy sources are particularly well-suited for developing countries and are already cost-effective. While the need to develop global agreements on energy use presents a great challenge, it also offers significant opportunities for the United States -- and other nations -- to develop expanded international markets for efficiency and renewable technologies.

We recommend that the Uni- States call for an international convention to address future world energy usage and develop global strategies to limit carbon dioxide and other greenhouse gas emissions.

We also recommend that the United States seek a total phase-out of chlorofluorocarbons (CFCs), since CFCs contribute nearly 20 percent of all greenhouse gas warming. Because CFCs are heavily used in energy applications, i.e., refrigeration and air conditioning, development of efficient substitutes should be accelerated.

CONCLUSION

The nation is at a crossroads. Government actions will be required to address these energy problems in a timely way. The government must take an activist stance but -- knowing that strictly regulatory approaches do not work -- seek to tap the power of the market through its actions.

As energy policy decisions are made, policymakers must be careful not to think they have solved one energy or environmental problem, only to inadvertently exacerbate another one. For this reason, we urge that energy policy options be examined through a comprehensive "greenhouse lens" as part of the decisionmaking process.

The environmental/energy problems of today are global in scope and require global cooperation if they are to be resolved. The United States should move aggressively domestically -- and provide international leadership on these critical issues. The industrialized nations of the world have a special responsibility to take leadership. The United States and the Soviet Union as the world's largest users of fossil fuels should assume leadership and work cooperatively in taking steps to slow and halt global warming.

Statement of

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and

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American Council for an Energy-Efficient Economy

before a joint hearing of

Hazardous Wastes and Toxic Substances
and
Environmental Protection

Subcommittees of

Committee on Environment and Public Works

U.S. Senate

on

S.2666

The Global Environmental Protection Act of 1988

16 September 1988

Statement of
William U. Chandler
on S.2666
The Global Environmental Protection Act of 1988

The sponsors of S.2666, the Global Environmental Protection Act of 1988, deserve strong credit for recognizing the risks of global environmental change. It is especially gratifying that S.2666 places priority on energy-efficiency measures for reducing global warming caused by anthropogenic carbon dioxide emissions. The legislation articulates appropriate concern and establishes strong measures for dealing with this enormous problem. The bill's finding that measures for reducing the risk of climatic change would also benefit the U.S. economy and its security is particularly insightful. (See Attachment 1.)

The chief significance of S.2666 is that it recognizes that effective measures can be taken to reduce greenhouse gas emissions. A substantial body of technical and economic research supports this conclusion.[1]

Many concerns in S.2666 parallel those expressed in Energy Efficiency: A New Agenda, published recently by the American Council for an Energy Efficient Economy. The Agenda was prepared with the participation of experts from 30 scientific and policy organizations. It sets out priorities for reducing energy-related threats to the nation's environment, security, and economy. The Agenda's first four recommendations detailed energy-efficiency policies to reduce the risk of global warming, ozone depletion, and acid rain, and have relevance to S.2666. (See Attachments 1 and 2.) Like S.2666, the Agenda found that energy-efficiency measures taken to reduce the risk of climatic change could also benefit the U.S. economy and national security.

> Unchecked fuel use could irrevocably alter the global environment. Atmospheric warming caused, in part, by the greenhouse effect of fossil fuel emissions could shift rainfall patterns and raise sea levels. The U.S. breadbasket could be turned into a dust bowl. East-Coast beaches might be eroded forever. Evidence is mounting that these changes are already underway, but the world need not wait for proof--energy efficiency can greatly reduce the risk of climate change and it can be justified entirely on its own economic merits.[2]

Energy-Efficiency As A Priority

The Global Environmental Protection Act of 1988 recognizes that anthropogenic carbon emissions continue to grow.[3] Indeed, many analysts have projected continued growth of global fossil-fuel carbon emissions, with year 2075 levels reaching perhaps 20 billion tons per year, almost four times the 1980s level.[4] If 55 percent of the carbon dioxide remained in the atmosphere, the atmospheric concentration in the year 2075 would be about 600 ppm, compared with about 348 ppm today. In this scenario, many of the severe environmental consequences described in S.2666--the decline of American forests, agriculture, and beaches--might be inevitable.

Important changes must be made in energy policies to keep global carbon emissions from growing to projected levels. Actually cutting current global emissions by one-fifth by the year 2005--as recommended by the Toronto

Conference on the Changing Atmosphere--will require very strong energy-efficiency policy. Technical and economic means can, however, be described for achieving the Toronto goal, though implementing them will not be easy. A 2 percent annual rate of energy efficiency improvement worldwide would be necessary to hold emissions constant, while meeting the Toronto goal would require a 3.3 percent rate. (See Attachment 3.) The OECD countries--including the United States--approached the higher rate during the early eighties when energy prices were escalating sharply and governments were making strenuous efforts to encourage conservation.[5] According to recent assessments, rates of efficiency improvements up to 3.6 percent per year are economically and technically feasible.[6]

Efficiency Works

The most important lesson gained from the energy policy experience of the last 15 years is that energy efficiency works. Nothing has so dramatically improved the American energy situation as energy efficiency. The United States in 1987 used little more energy than in 1973, yet produced 40 percent more goods and services. Efficiency has, in effect, cut the nation's annual energy bill by $160 billion.

Technology already exists to continue these gains. Numerous efficient products and processes--appliances, lighting products, building techniques, automobiles, motor drives, and manufacturing techniques--have been developed and commercialized by private companies in the United States and other industrialized countries.

Despite this promise, the momentum for energy efficiency appears to be diminishing. U.S. energy efficiency declined 3.5 percent in the first quarter of this year.[7] Energy use in the first 5 months of 1988 is nearly 7 percent higher than for the same period a year earlier, and the increase is occuring across all sectors of the economy. If this trend is sustained, it will increase U.S. annual carbon emissions by at least 80 million tons. This fact dramatically underscores the importance of energy efficiency policy and the timeliness of S.2666. It emphasizes the need for policies that can be initiated quickly, however, and ones that are as effective as possible.

Criteria for Developing Climate Policy Priorities

Energy Efficiency: A New Agenda based policy recommendations for controlling carbon emissions on three principles: effectiveness, fairness, and timeliness. It was concluded that energy efficiency is essential for effectiveness in reducing the risk of climatic change. Dollar for dollar, efficiency investments in general provide greater carbon emissions reductions than energy supply alternatives. (See Attachment 4.) Economic modelling results suggest that without strong and continued improvements in energy efficiency--or some unprecedented "breakthrough" in energy supply technology--there is substantial chance that atmospheric carbon dioxide levels could double during the next century.[8]

The perception of fairness in energy-efficiency policy will be critical to its success. S.2666 correctly notes that the United States bears a heavy burden for reducing carbon emissions. This country produces about one-quarter of global carbon emissions with less than 5 percent of the world's population. Indeed, each American produces more carbon with his or her car than the average world citizen does in all activities. We should not lose sight of the fact, however, that climatic change is a global problem and will require both a global solution and strong U.S. leadership. Fortunately, energy efficiency can improve economic well-being in most nations.

Carbon emissions control policies can be fair if they leave consumers better off. For this reason, efficiency policies for cutting carbon emissions will more likely be accepted if they are strictly cost-effective. Fortunately, a requirement for cost-effectiveness should increase, not decrease, the efficacy with which carbon emissions are reduced. An efficiency investment that costs more than electricity or coal also costs much more than myriad other energy-efficiency opportunities. If it cost twice as much as an available conservation investment, then it would save only half as much carbon per dollar invested.

The Agenda statement and S.2666 are in agreement that the United States should pursue early action. The former, however, stresses that actions which can be justified for their economic value be given first priority. Because energy efficiency measures save consumers money and provide security benefits, they can be applied to reduce risks of climatic change without the

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need for proof--or general acceptance of proof--that climatic change is underway.

Energy Efficiency: A New Agenda articulated goals and means similar to S.2666, but includes important differences. The chief differences reflect the fact that the Agenda:

- Contains only policies which the authors believed would save energy for less than the marginal cost of energy supply.
- Addresses a broad scope of energy-using activities.
- Stresses complementary policy approaches.
- Proposes a global energy-efficiency initiative.

Cost-Effectiveness

One might imagine that consumer cost should be a secondary concern in an effort to reduce carbon emissions and the risk of climatic change. But just as some energy sources are cheaper than others, some energy-efficiency measures save more per dollar than others. The carbon dioxide limits specified by S.2666 for light duty vehicles implies a fuel economy standard of about 45 mpg. This level matches that recommended by the Agenda for automobiles as technically achievable and cost-effective. This provision could represent the most important energy and carbon savings measure in the legislation.

Cost-effectiveness of energy-efficiency measures in buildings can vary by region and application, due to widely varying fuel and construction costs. Thus, a regulatory approach permitting sale of only the most-efficient gas furnace available could save consumers money in cold northern states but not in warmer areas. The furnace would cost more when purchased, but the reduced fuel consumption could quickly pay for itself in cold regions. Yet in warmer southern states, lower annual heating loads might mean the more-expensive furnace would not pay for itself within a few years. The southern consumer--and the global climate--would benefit more from highly efficient air conditioning equipment. The higher furnace cost might even push a homeowner or builder to install electric resistance heating, instead of a more-efficient (but not the most-efficient) furnace, with the end result counterproductive to the intention of S.2666. Any legislation setting a single "best available technology" standard for all heating and cooling equipment may create such problems. The National Appliance Energy Conservation Act of 1987 (NAECA) sets initial standards and a procedure for upgrading these standards. NAECA should ensure continuing, significant efficiency improvements in this area. New legislation that targeted other end uses would be most likely to stimulate efficiency improvements.

The Agenda project described mechanisms intended to motivate utilities to develop cost-effective building (and industrial) sector conservation resources. One such approach would modify the utility regulatory structure to make it attractive for utilities to acquire energy efficiency resources. Utility regulatory bodies could link utilities' profitability to progress in acquiring efficient, cost-effective sources of generating capacity and end-use efficiency. Financial incentives and penalties could take a number of forms. For example, if a utility performs admirably in acquiring "conservation resources", it may be appropriate to increase a utility's rate of return or earnings. If a utility performs poorly in pursuing cost-effective opportunities for greater efficiency, regulators could penalize the utility by lowering its allowed rate of return. Establishing performance-based incentives would safeguard consumers from paying for ineffective or overly expensive conservation, load management, and alternative generation programs. Thus, regulators could base incentives (or penalties) on the amount of savings achieved, the cost effectiveness of conservation programs, or on a utility's ability to reduce the total energy bill of its customers.

A few state commissions have used incentives and penalties and rate adjustments along the lines suggested here. In 1979, the California commission penalized Pacific Gas & Electric Co. (PG&E) for failing to make reasonable efforts towards developing cogeneration potential in its service territory.[9] PG&E subsequently contracted for large amounts of cogeneration and independent power. In 1986, the Massachusetts commission reduced the allowed rate of return for Boston Edison Co. (BECO) because of its poor record in developing and implementing conservation and load management programs and performing integrated planning. Since then, BECO established or expanded about 20 demand side management programs. The Wisconsin commission is also using performance-based incentives as part of its effort to stimulate much larger and more effective conservation programs among Wisconsin's utilities.[10]

Basing the incentive on conservation program performance or a utility's overall progress in reducing customers' bills requires careful evaluation. The federal government could assist state commissions in addressing these problems. The Agenda project proposed that the Department of Energy (DOE) analyze alternative incentive schemes including conducting case studies of recent initiatives through its Least-Cost Utility Planning project.

Providing utilities with incentives for pursuing least-cost energy services helps to institutionalize competitive forces within the regulatory framework. A parallel strategy would be to allow energy conservation projects and vendors to compete with suppliers of energy when a utility obtains new resources through bidding procedures. This form of "market testing" in turn would aid utilities that are developing least-cost plans.

Scope of Energy End-Use Policy

S.2666 goes beyond the Agenda project by specifying efficiency improvements for electric energy conversion. The Agenda did not make energy supply recommendations. In terms of energy end-uses, S.2666 emphasizes the efficiency of consumer appliances and automobiles. It probably underemphasizes industrial energy use because, although great strides have been made, many opportunities for energy efficiency remain. The Agenda suggested that a highly-efficient energy future could save over 18 quadrillion BTU per year over current trends, with industry accounting for about half of the difference in these scenarios. (See Attachment 5.) The Agenda described a major government-industry cooperative research and development effort which would improve energy efficiency in combination with overall productivity improvements, an approach which would have benefits for U.S. international competitiveness as well as the global environment.

The Agenda emphasized the need for efficiency in the transportation sector. In addition to fuel economy standards, it recommended a transportation fuel tax. This tax would help stimulate the demand for high efficiency cars. Without this impetus, fuel economy standards alone might fail. Moreover, fuel taxes would stimulate efficiency improvements in the short run by increasing consumer awareness of the value of gasoline. The Agenda found that a tax of at least $0.30 to $0.50 per gallon was justified to reduce oil imports and the trade deficit and security problems imports impose.

Several of the policies discussed in the Agenda fall primarily in the jurisdictions of other Senate committees. But unless Congress can take a unified approach to energy-efficiency policy making, the goals of S.2666 may not be achieved.

The Need for Complementary Policies

The Agenda project recognized the need to take complementary approaches to solving problems of energy inefficiency. Problems of market failure sometimes require regulatory initiative, particularly when external, or environmental, costs are not reflected in energy costs. This is most often the case in regulated electricity and natural gas markets, where prices reflect average rather than marginal costs. In such markets consumers do not receive correct signals regarding the real value of energy, and it has been traditional for the U.S. government to attempt to ameliorate such situations, usually through regulation.

When energy prices paid by consumers differ greatly from their total costs, however, consumers generally respond better to a mixture of regulatory, price, and information programs. Increases of 28-80 percent in the efficiency of new refrigerators, freezers, and air conditioners between 1972-86 evince, in no small part, the success of regulatory policies of state governments. But investments in appliance-efficiency research also made the improvements possible. Other contributing factors were a 25 percent real price increase in residential electricity over the period, the federal labeling program, and financial incentives provided by many utilities.[11]

Similar lessons can be learned from the nation's experience with fuel economy regulations. Improvements are extremely hard to win if consumers give no thought to saving fuel when they buy and operate their cars--even though the investments would save them money. As long as the price of gasoline at the pump is extremely low, as it is today in the United States, the need to conserve gasoline will not be a major factor in automobile purchases. (See Attachment 6.) Though consumers could save money by buying a car that obtained more than 45 mpg, the amount of money saved would be of relatively small gain to the individual, as opposed to society as a whole, and so consumers often ignore it. But millions of such decisions add up to serious trouble for the nation's environment and economy. The Agenda recommended that complementary policies--fuel economy standards, fuel taxes, and research efforts--be applied to stimulate energy efficiency in automobiles and light trucks. Fuel taxes deserve serious consideration as part of a comprehensive program to reduce global warming.

Global Initiatives

Title III of the Global Environmental Protection Act recognizes the importance of international cooperation in environmental protection. Energy Efficiency: A New Agenda emphasized the importance of global cooperation in energy efficiency, including the Soviet Union and developing countries. Without the cooperation of these regions, stabilizing carbon emissions--let alone the atmospheric concentration of carbon dioxide in the atmosphere--will be impossible.

Large efficiency gains should accrue in developing countries because the energy intensity of major Third World economies--the energy used per unit of GNP--is often exceedingly high. The energy required per unit of output in China and India, for example, is twice that of the United States and four times that of Japan and West Germany. China and India have energy intensities twice that of nations at comparable stages of development today. This high intensity results directly from technically and economically inefficient energy conversion and end-use technology.[12] Yet these nations have the most to gain from efficiency improvements. Analytic modelling results suggest that energy-efficiency would not only reduce carbon emissions, but would increase per capita incomes in developing nations.

Conclusion

The Global Environmental Protection Act of 1988 is an important legislative landmark. It recognizes the importance of global climate change and it acknowledges essential means of reducing environmental risks. Its goals and priorities parallel those of the group of 38 experts who contributed to Energy Efficiency: A New Agenda. But certain provisions of S.2666 could be modified to better achieve its objectives. The Agenda recommended 21 policy measures for stimulating energy efficiency, each selected on the basis of importance, technical feasibility, and cost-effectiveness. Greater incorporation of this broad approach to energy end-use in S.2666, rooted in the energy policy experience of the past 15 years, would better assure that the nation accomplishes the act's worthy goals.

ATTACHMENT 1: S.2666 AND ENERGY EFFICIENCY: A NEW AGENDA SHARE COMMON GOALS

Section 115 Provides the Rationale for S.2666 (an excerpt):

> (21) [T]echnologies and practices exist which could reduce carbon dioxide substantially;
>
> (22) the adoption of these technologies and practices would increase the efficiency and competitiveness of the United States business and industrial sector, decrease the Nation's dependence on foreign supplies of fuel, protect the agricultural sector, preserve the natural environment, and simultaneously achieve reductions in other chemicals which cause acid rain, ground level ozone, and fine particle pollution; and
>
> (23) therefore, the United States can protect the global environment directly by reducing emissions of carbon dioxide...and indirectly protect such environment by demonstrating the technologies and practicies which can be applied elsewhere.

A panel of 38 energy experts reached similar conclusions in preparing ENERGY EFFICIENCY: A NEW AGENDA:

> Energy efficiency offers U.S. leaders a practical means of achieving national goals. It protects the environment--in the short run by reducing acid rain and in the longer run by reducing the risk of global climatic change. It strengthens U.S. security at a time when domestic oil production is declining and we are becoming excessively dependent on oil imports. Energy efficiency enhances the competitiveness of U.S. industry in world markets by reducing the cost of production, and serves the consumer by cutting lighting, cooling, and heating costs in homes and offices. It creates jobs and helps hold down interest rates. No energy supply option can provide all these benefits.

ATTACHMENT 2: ENERGY-EFFICIENCY POLICY PRIORITIES

Policies for an Energy-Efficient Economy

Goal: Reduce U.S. energy intensity by 2.5% per year

Applying energy efficiency to protect the national and global environment

1. Reduce the risk of climatic change through an international energy-efficiency protocol.
2. Establish Soviet, American, and OECD cooperation to promote energy efficiency on a global basis.
3. Develop technologies that simultaneously save energy and protect the stratospheric ozone layer.
4. Use emissions ceilings for acid rain control.
5. Encourage integrated energy and environmental planning at the state and federal levels.

Doubling car and light truck fuel economy to cut oil imports

1. Raise gasoline and diesel fuels taxes by 10 cents per gallon for at least three consecutive years.
2. Raise car and light truck fuel economy standards to 45 and 35 mpg, respectively, by the year 2000.
3. Establish a gas-guzzler tax, gas-sipper rebate program.

Promoting least-cost utility services

1. Provide utilities with financial incentives to promote energy efficiency and least-cost energy services.
2. Allow energy-efficiency investments to compete with energy supply options in competitive bidding schemes.
3. Encourage least-cost planning through federal regulation of interstate power sales.
4. Conduct research and evaluation to improve utility, state, and local energy conservation programs.

Enhancing industrial competitiveness with energy-efficiency research

1. Increase the commitment to federal energy-efficiency research and development and re-establish the federal role in demonstrating new energy-efficient technologies.
2. Establish research centers for energy-intensive industrial processes.
3. Establish a program to monitor and distribute information on foreign energy efficiency research.

Making buildings more efficient to improve their affordability

1. Improve the effectiveness of and increase funding for low-income weatherization, especially for multi-family buildings.
2. Establish federal minimum efficiency standards for fluorescent and incandescent lamps.
3. Improve the energy efficiency of federal buildings.
4. Expand federal technical assistance for conservation efforts.

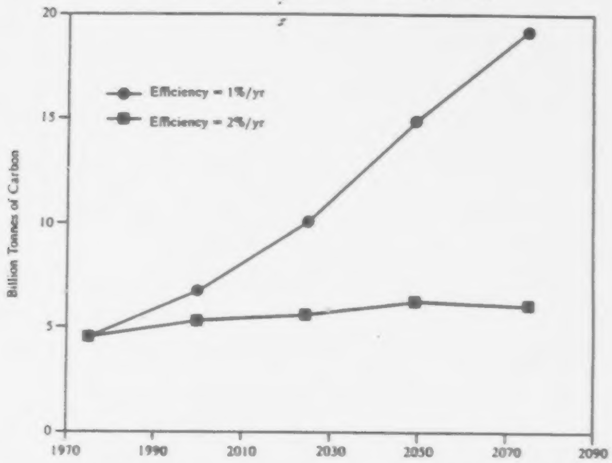
Helping developing nations acquire skills and technology for energy efficiency

1. Modify the energy planning and lending policies of the World Bank and other multilateral lending and development institutions.
2. Provide technology and policy assistance for energy efficiency to developing countries through U.S. and other American agencies.

SOURCE: W.U. Chandler, H.S. Geller, and M.R. Ledbetter, Energy Efficiency: A New Agenda (Washington, D.C.: American Council for an Energy-Efficient Economy, 1988).

ATTACHMENT 3

Global Carbon Emissions and Energy Efficiency



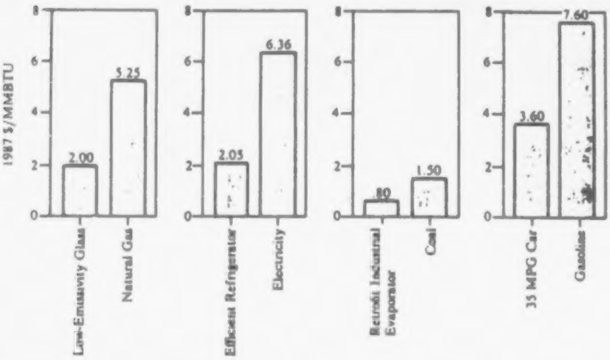
Energy efficiency: A Tool for Slowing Climatic Change

The above cases show two future carbon emissions scenarios which differ only in their assumption for the global rate of energy-efficiency improvement. Relatively high economic growth would be permitted in either case. To achieve the higher efficiency scenario, implementation of policies such as those suggested in this document would be necessary.

SOURCE: W. Chandler, "Carbon Emissions Control Strategies: The Case of China," forthcoming in Climatic Change.

ATTACHMENT 4

Cost of Energy Saved vs. Cost of Energy Supply



Energy Efficiency: The Cost Advantage

The cheapest way to satisfy growing demand for energy services is to invest in energy efficiency. Home insulation costs far less than nuclear or coal-fired electricity. Auto fuel economy can be built into new cars for less than the price of gasoline. Industrial retrofits save money even with today's low energy costs. The cost advantage shown above does not even count the environmental and national security benefits that energy efficiency inherently offers.

SOURCE: American Council for an Energy-Efficient Economy

ATTACHMENT 5

Scenarios for U.S. Energy Use in 2000

	Energy Use (Quads)			
Sector	*Actual 1987 (a)*	*High efficiency 2000 (b)*	*Moderate efficiency 2000 (b)*	*EIA base case 2000 (c)*
Residential	15.7	15.6	17.3	18.3
Commercial	11.9	13.3	14.7	15.1
Industrial	27.2	23.8	28.0	33.8
Transportation	21.2	18.5	21.0	22.3
Total	76.0	71.2	81.0	89.6

Notes:

(a) "Monthly Energy Review," DOE/EIA-0035(87/12), Energy Information Administration, Washington, DC, Dec. 1987. This source combines residential and commercial energy use; the division shown above is based on the 1985 breakdown.

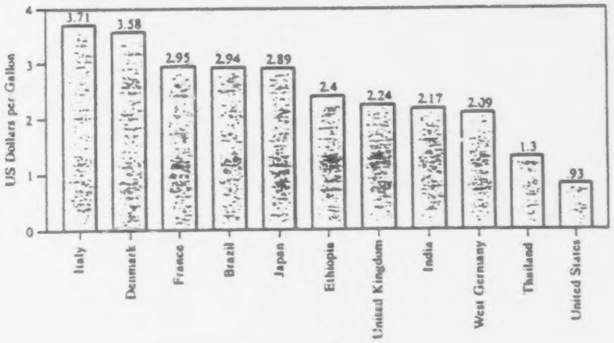
(b) Based on Reference 137.

(c) "Annual Energy Outlook 1987," DOE/EIA-0383(87), Energy Information Administration, Washington, DC, March 1988.

SOURCE: American Council for an Energy-Efficient Economy.

ATTACHMENT 6

Gasoline Price Levels, Selected Countries, 1987



Foreign nations tax gasoline heavily, encouraging efficiency

Gasoline in Italy and Denmark costs four times as much as in the United States. This difference is due almost entirely to differences in gasoline tax levels. Low U.S. gasoline prices encourage consumption and place the nation at risk of new oil supply disruptions, price hikes, and reduced flexibility in foreign policy.

SOURCE: International Energy Annual, *1986 Energy Information Administration, U.S. Department of Energy, October, 1987.*

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BREAKING OUT OF THE HEAT TRAP:

Energy Policy, Global Security, and the Greenhouse Effect

Testimony by

Dr. Irving Mintzer
World Resources Institute

To

The Committee on Environment and Public Works
United States Senate
Washington, D.C.

September 16, 1988

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ABSTRACT

Air pollution caused by energy use, agriculture, and other industrial activities is changing the composition and behavior of the atmosphere. Effluents from these activities are combining with releases from biotic sources to alter the planet's radiation budget, increase the acidity of rainfall, and enhance the probability of surface exposure to ultraviolet radiation. The impacts of these emissions are increasingly visible to scientists, politicians, and the general public. The impacts are popularly referred to as stratospheric ozone depletion, global warming due to the greenhouse effect, and forest death or acid rain. Because the pollutants causing these problems arise from the same set of activities and interact chemically in the atmosphere, policy choices made to reduce or mitigate any one of these problems will inevitably and inextricably affect the other two.

Policy choices made today and implemented over the next several decades can substantially affect the timing and extent of global warming. The goals and objectives outlined in S.2666, "The Global Environmental Protection Act," would, if achieved, substantially reduce the U.S. contribution to future global warming and ozone depletion. Identification of such goals is an important step in the policy process and will hasten the development of constructive and effective responses to the linked problems of ozone depletion, global warming, and ground-level air pollution. The individual performance standards specified in S. 2666 can be reached with technology that is commercially available or close to introduction today. The overall objectives of the bill, to reduce future emissions of carbon dioxide by 50% and to eliminate the risk of future ozone depletion, can not, however, be achieved by the measures specified unless current rates of growth in energy demand are reduced by improvements in the efficiency of energy use.

Therefore, the most important energy policy options for reducing the rate of global warming include (1) increasing the efficiency of energy use through technical improvements and through changes in pricing policy to eliminate subsidies, (2) fuel-switching to less carbon-intensive fuels and the development of renewable technologies, and (3) reducing the use of the most dangerous CFCs. A wide range of cost-effective measures are available today to reduce the U.S. contribution to future global warming. These measures fall into three categories: (1) getting the prices right, (2) reducing emissions at the source, and (3) offsetting future emissions to reduce their effect. Promising candidates include (1) introduction of a tax on gasoline starting at 2 cents per gallon and increasing 2 cents per gallon per month for four years, (2) instituting a carbon tax made revenue-neutral through tax credits for investments in energy efficiency, (3) demonstrating in all federal buildings those energy efficiency measures certified cost-effective by the Secretary of Energy, (4) demonstrating through joint public-private ventures some of the new high-efficiency electricity supply technologies that are spin-offs of military R and D, (5) requiring that all bilateral and multilateral aid projects evaluate the effects on greenhouse gas emissions and the potential for increasing efficiency before expanding energy supply, and (6) amending the New Source Performance Standards for stationary sources to require that new stationary sources secure offsets for their additions to local emissions of greenhouse gases.

Implementation of these and other specific measures to carry out the broad policy strategies outlined above can postpone for as much as sixty years the global commitment to a warming equal to the effect of doubling the pre-industrial concentration of CO_2 alone.

Mr. Chairman and members of the Committee, my name is Dr. Irving Mintzer. I am Senior Associate in the Energy, Climate, and Air Pollution Program at the World Resources Institute, a not-for-profit policy research center in Washington, D.C.. I have been engaged in the policy debate on energy and climate change for the last five years, both in the United States and in the international scientific community. I recently returned from the 38th Annual Pugwash Conference on Global Security and Common Problems. At this meeting, 200 scientists, diplomats, and defense analysts from 38 countries issued a declaration emphasizing the important linkages between the international environmental problems we focus on here today, the challenges of sustainable development for Third World states, and the military risks to national security. I would like to ask the Committee to have this Declaration of Dagomys entered into the record with my testimony.

I am honored to have the privilege of presenting my views to this Committee during its consideration of the Global Environmental Protection Act, S.2666. The problems of global climate change, stratospheric ozone depletion, and ground-level air pollution are intimately and inextricably linked to choices concerning U.S. energy policy. The complex question of how to control the rate of at which these environmental effects emerge will be one of the critical challenges to sustainable development in the next several decades. The work of this body will be an essential contribution to policy development in the United States as well as to emerging international efforts to address the linked issues of stratospheric ozone depletion and global warming due to the greenhouse effect. My testimony today will concentrate on the provisions of S.2666 that pertain to the reduction of future emissions of carbon dioxide (CO_2). I hope that our dialogue today will help you to identify policy options that can encourage continued economic growth in the U.S. while minimizing long-term environmental damages.

In sharing these remarks with you, I would like to acknowledge the generous help of my colleagues at the World Resources Institute in its preparation, especially Dr. James MacKenzie and Dr. Michael Walsh.

I. SUMMARY

Air pollution caused by energy use, agriculture, and other industrial activities is changing the composition and behavior of the atmosphere.[1,2,3] Effluents from these activities are combining with releases from biotic sources to alter the planet's radiation budget, increase the acidity of rainfall, and enhance the probability of surface exposure to ultraviolet radiation. The impacts of these emissions are increasingly visible to scientists, politicians, and the general public. The impacts are popularly referred to as stratospheric ozone depletion, global warming due to the greenhouse effect, and forest death or acid rain. Because the pollutants causing these problems arise from the same set of activities and interact chemically in the atmosphere, policy choices made to reduce or mitigate any one of these problems will inevitably and inextricably affect the other two.

The most important compounds affecting the extent and timing of global warming -- the principal subject of this hearing -- are carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), tropospheric ozone (O_3), chlorofluorocarbons (CFCs), and the related bromine-containing compounds, the Halons.[4] If current trends continue, emissions of all of these gases will continue to grow. By 2030, the cumulative effect of these emissions will be to commit the planet to an average surface warming of 3-9° F, an amount equal to that of doubling the pre-industrial concentration of CO_2 alone.[5] This rise in temperature will cause an increase in average global sea levels of one to four feet, with significantly higher ocean levels in regions where coastal subsidence is also occurring.[6] The patterns of winds and ocean currents will shift, disrupting traditional regional climates and altering rainfall. Recent analyses with general circulation models of the atmosphere indicate that mid-continent, mid-latitude areas may become hotter and drier.[7] These changes in the global radiation budget may significantly increase the frequency of extreme weather events, including droughts, floods, and severe storms. (See Table 1.) The recent incidents of drought in the U.S. mid-west, heat waves in India, hurricanes in the Carribean, and floods in Turkey and the Sudan, though not necessarily caused by the greenhouse effect, are indications of the kind of toll which may be inflicted on societies by changes in climate. Table 2 illustrates some of the economically important impacts of global warming.

At the same time that the changes in global climate are increasing the stresses on economic societies and natural ecosystems, increased exposure to ultraviolet (UV) radiation caused by stratospheric ozone depletion will complicate the problem. The same continued trends in emissions growth would commit the globe to an eventual depletion of total ozone of between six and ten percent. Enhanced exposure to UV will increase the incidence of some forms of skin cancer, accelerate the onset of cataracts and other eye diseases, and may reduce the effectiveness of the human immune system to fight off infectious diseases. Increased levels of UV exposure will increase urban smog and may further reduce forest and crop yields.[8]

For the most part, the performance standards outlined in S.2666 can be achieved with technologies that have already demonstrated commercial feasibility in the U.S. or in other advanced industrial economies. In a few cases, further development will be required for key technologies that are now close to commercialization.

Despite the introduction of these more fuel-efficient and less polluting technologies, however, the overall objectives of this bill cannot be met without increasing the efficiency of energy use. In effect, if current growth trends in energy demand continue into the next century, the emissions reductions resulting from implementation of the performance standards contained in the

Stafford-Baucus bill will be dwarfed by the effects of increases in energy demand. Achieving the intended purpose of this bill, to protect the global environment from extensive, human-induced destruction, will require additional measures to squeeze more economic benefit and more useful work from each ton of coal or barrel of oil that the U.S. burns in the years ahead. These goals can be accomplished in an economically efficient manner, but only if investments to improve energy efficiency are allowed to compete on a level playing field with options to expand supply and reduce emission rates. Both elements will be essential components of any solution strategy adequate to the task ahead. By giving states and local governments the greatest possible flexibility to determine the optimal approach to achieving emissions reductions, Congress can substantially increase the likelihood of achieving these goals at the lowest overall cost to the country.

II. ENERGY USE AND THE RATE OF FUTURE GLOBAL WARMING

The global pattern of energy supply and use will substantially determine the rate of future emissions of greenhouse gases, especially CO_2 and N_2O. It will also affect the rate of increase in the atmospheric concentration of methane and tropospheric ozone. In the near term, efforts to make energy use more efficient by using foam insulation in buildings and in certain home appliances will affect the magnitude of future releases of CFCs. The rate of growth in emissions of all these gases will be affected by choices made in the next decade that affect the relative prices of various fuels.

Annual worldwide emissions of CO^2 from the combustion of fossil fuels are equal to about 5.2 billion metric tons of carbon, approximately 70-80 percent of total emissions. Emissions of CO_2 from the biota add another 1 to 2 billion metric tons of carbon to the atmosphere each year, representing the remaining 20-30 percent of global emissions. A large fraction of these biotic emissions result from the burning of biomass for energy and the destruction of tropical forests to clear land for agriculture. As a result of the emissions from all these sources, the atmospheric concentration of CO_2 is increasing by about 0.4 percent per year. (See Table 3.)

Carbon dioxide emissions have historically contributed over half of the total atmospheric commitment to future global warming. During the last century, the U.S. has been the largest contributor to global emissions of CO_2 from fossil fuels. In 1985, the U.S. emitted approximately 25% of the CO_2 released from fossil fuel combustion. Table 4 illustrates the geographical distribution of CO_2 emissions from fossil fuels during the last 25 years.

Most of the other greenhouse gases, however, are more efficient absorbers of the Earth's infrared radiation on a per-molecule basis than is CO_2, and their concentration in the atmosphere is increasing at a more rapid rate. The addition of a single molecule of CFC-11, for example, can have an ultimate effect on global warming that is equal to the addition of 10,000 molecules of CO_2. One recent analysis, recognizing these relative impacts, suggests that, if current trends continue until 2030, the contribution to global warming from the non-CO_2 trace gases will amplify the warming due to CO_2 alone by between 100-250 percent.[8a]

Not all fossil fuels contribute equally to the build-up of atmospheric CO_2. Table 5 illustrates the CO_2 emissions per unit of heat supplied from burning various fossil fuels. Table 6 illustrates the CO_2 emissions resulting from burning various synthetic fuels. On a global basis, coal and other solid fuels contributed approximately 44 percent of total CO_2 emissions from burning fossil fuels in 1985. Combustion of liquid petroleum products contributed an additional 40 percent, and natural gas added about 15 percent.

In the U.S., the contributions from various fuels were somewhat different for the global pattern last year. As shown in Table 7, oil burning contributed approximately 49 percent of the total energy supplied by fossil fuels and about half of all CO_2 emissions. Coal combustion, which contributed approximately 26 percent of total fossil energy, released about 33 percent of the CO_2. Natural gas supplied the remaining 25 percent of fossil fuel-derived energy and emitted 18 percent of the CO_2.

Approximately two-thirds of U.S. CO_2 emissions arise from the transportation and electric power sectors. About 25 percent is emitted by industrial activities and about 12 percent from end-uses in the residential and commercial sector. (See Table 8.)

As Table 8 illustrates, the mix of fuel sources contributing to these emissions varies among the sectors. In the transportation sector, virtually all the emissions are from combustion of fluid fuels, 98 percent of which is oil. Coal burning contributes about 85 percent of the CO_2 emissions from the electric power sector. Nine percent of the emissions from the electric sector come from burning natural gas and the remaining 6 percent from burning oil. In the industrial sector, 50 percent of the emissions are from oil burning, about 30 percent from combustion of natural gas and the remaining 20 percent from coal. Natural gas burning generates almost two-thirds of the emissions from the residential and commercial sector with virtually all the rest released from burning oil.

Since 1973, global use of natural gas and coal have increased by about 36 percent. Oil use in 1986 is back to approximately the same global consumption level as in 1973. Over the same period, the amount of gas vented and flared has fallen by 53 percent. Global CO_2 emissions from fossil fuels have shown similar patterns. (See Table 9.) CO_2 emissions from the combustion of coal and natural gas have increased by about 2.4 percent annually, while those from burning petroleum have increased by less than 0.2 percent per year. For the ensemble of commercial fossil fuels, global CO_2 emissions have increased by about 17 percent in the last 13 years, implying a growth rate of 1.2 percent per year.

All nations have not contributed equally to global emissions of CO_2. The historical balance is shifting, with developing countries and centrally planned economies playing a growing role in the future. The United States, which currently consumes about 30 percent of the fossil fuels used globally each year, produced about 25 percent of the fossil-fuel-derived CO_2 in 1985. The Soviet Union contributed about 20 percent of fossil-fuel-derived emissions in 1985, Western Europe about 15 percent, China about 10 percent, and Japan about 6 percent. In 1985, developing countries (excluding China) added about 15 percent.

This pattern has changed substantially over the last 25 years. (See Table 4.) The most dramatic and important shift is in the role of developing countries. In 1960, these countries contributed less than 8 percent of global CO_2 emissions from fossil fuel use while the United States produced almost 33 percent. At that time, the share emanating from Western Europe was 21 percent while the Japanese share of global emissions stood at 3 percent. As the levels of population and energy use increase in developing countries during the next 25 years, their share of global emissions is sure to grow. How fast emissions increase will be determined largely by the national energy strategies chosen by these countries and financed by the development assistance community.

On the biotic emissions side of the ledger, net increases of CO_2 in the atmosphere occur only when the amount of stored carbon that is burned exceeds the amount of carbon dioxide converted to plant matter by photosynthesis. If the quantity of material harvested and burned each year is limited to the amount of new biomass grown during the same period, CO_2 is cycled through the atmosphere but no net increase occurs. Fuel derived solely from the annual yield of agricultural crops or silvicultural plantations does not add to the atmospheric burden of CO_2.

Part of annual nitrous oxide emissions are also due to fossil fuel combustion. The burning of coal and residual fuel oil contributes most of the fossil-fuel derived releases. Combustion of natural gas and other petroleum products adds a smaller and somewhat uncertain amount.

All fossil fuel combustion releases other oxides of nitrogen (NO_x) that contribute to the formation of tropospheric ozone. In addition, releases of carbon monoxide (CO) from the combustion of biomass and fossil fuels tend to increase the rate of growth in methane concentration.

III. ENERGY POLICY AND THE RISKS OF FUTURE GLOBAL WARMING

The key to reducing the joint risks of global warming and stratospheric ozone depletion is to reduce the rate of buildup of the offending trace gases. Table 3 illustrates the present concentrations and rates of increase for the most important trace gases affecting the rate of global warming.

Substantial opportunity now exists to alter the rate of future greenhouse gas emissions. The performance standards for individual devices outlined in S.2666 can, in most cases, be achieved with equipment commercially available today. For example, the CO_2 standards for stationary sources set forth in Section 116 (a)(1)(B) sub-parts (1) and (2) can be met by existing utility power plants. The average U.S. coal plant operating at approximately 34% efficiency releases about 630 pounds of CO_2 per million BTU compared to the 610 pounds per million BTU required for plants built after 1990. By increasing plant efficiency to slightly over 35%, existing coal plant designs could meet the test of sub-part (1). The average U.S. oil plant releases about 435 pounds of CO_2 per million BTU when operating at about 31% efficiency. Oil-fired plants operating at this level meet the standard for 2000 given in sub-part (2). Coal-burning plants can only meet the year 2000 standard if they cogenerate heat and power. Current U.S. gas turbine power plants emit on average about 330 pounds of CO_2 per million BTU and operate at about 35% efficiency. To reach the standard of 280 pounds per million BTU set in sub-part (iii) for plants built after 2010 would require the use of advanced steam-injected gas turbines or combined cycle machines which operate at efficiencies of over 40% and are just now entering the commercial market. No currently available technology for the direct combustion of coal can meet the 2010 standards set in this bill.

The fact that machines now available or on the commercial horizon can meet the performance standards set for stationary sources in S.2666 is important but not sufficient cause for celebration. It is worth noting that the imposition of these standards will substantially constrain future investment choices by electric utilities and yet may nonetheless still lead to increases in the aggregate level of CO_2 emissions from this sector. Recent preliminary analyses by the Office of Technology Assessment and others indicate that if electricity demand grows at even 2% per year into the next century (compared to recent growth rates of over 3% per year), even with the provisions of S.2666, it will be very difficult to keep aggregate utility emissions of CO_2 at levels below those of 1986.

Recent advances in the technology of energy use have established that it is technically feasible to increase substantially the engineering efficiency of energy use without significantly increasing the costs of goods produced. Furthermore, experience during the last fifteen years in the U.S, the Federal Republic, even the Peoples' Republic of China has shown that growth in economic output is not locked into any fixed relationship to growth in energy use. In the U.S., for example, economic output has grown at an average annual rate of about 2.8% for the last decade while energy use has remained essentially constant. Similar examples exist throughout the member states of the Organization for Economic Cooperation and Development.

A few examples of recent technical success in improving the efficiency of electricity use stand out. In the residential and commercial sector, new fluorescent lighting systems offer the same light output as traditional incandescent bulbs with only 20% of the electricity input. These new bulbs provide a soft, attractive glow, have a payback period of three years or less, and reduce the cooling loads in buildings substantially. Refrigerator designs which are now available in the U.S. provide the same amount of cooled space as the average American machine of five years ago with only 50-75% of the electricity input. In the industrial sector, solid-state, variable-speed motor load controllers offer a potential improvement in energy efficiency of 30-40% for prime movers.[9] Equally impressive savings are now possible in the transportation sector.

In the transportation sector, Section 117 of S.2666 calls for reductions of CO_2 emissions from the current average of 400 grams per mile for new cars to 360 grams per mile (gpm) in 1990, 300 gpm in 1995, 200 gpm in 2000 and 100 gpm in 2010. This is roughly equivalent to setting a fuel economy standard of approximately 70 miles per gallon in 2010. Automobile performance at this level has already been demonstrated in four-passenger vehicles. Commercially available vehicles from Ford, Chevrolet, Nissan, Honda, and VW already exceed the standards for 1990, 1995, and 2000. Prototypes vehicles from VW, Volvo, Renault, and Toyota have met or exceeded the performance standard for 2010.

Despite these successes, it is not clear that the U.S. fleet average could be easily raised to the levels specified in S.2666. Even if it were, the aggregate level of emissions in 2030 might still exceed the 1986 level.

The difficulty of raising the fleet average to the levels specified in the Stafford-Baucus bill results from two factors: the aging of the fleet and the shift from cars to light trucks.

Figures 1 and 2, prepared by Dr. Michael Walsh, illustrate the average age of U.S. passenger cars and light trucks. The clear trend since 1970 is for U.S. vehicles to be kept on the road for increasing periods of time. This trend if continued, will slow the rate at which the total fleet fuel economy increases, regardless of the level at which the new car standard is set.

Figure 3, also prepared by Dr. Walsh, illustrates the historical trend in total vehicle miles traveled by cars, trucks, buses, and motorcycles since 1940. Although the average number of miles travelled per car has not grown substantially since 1950, the total vehicle miles travelled by the U.S. auto fleet has increased by nearly a factor of four over this period. As a consequence, despite increases in efficiency, Figure 4 illustrates that fuel consumption by U.S. automobiles has more than tripled during the same period. If total vehicle mileage grows at an annual rate of only 2% in the future (compared to about 3.5% per year during the last 35 years), and the current CAFE requirements remain in effect, fuel use by US autos will more than double again by 2030. If, on the other hand, the performance standards in S.2666 are implemented, Figure 5 illustrates that fuel consumption by US autos will decline by about 50% by 2030. As shown in Figure 6, Dr. Walsh has calculated the fuel savings from the Stafford-Baucus bill to be about 100 billion gallons per year in 2030, assuming a 2% per year growth in the total vehicle miles traveled by the fleet. This translates into an annual emissions reduction of 250 million metric tons of carbon due to the provisions of S.2666.

Despite this substantial achievement, other factors must be considered. If the recent trend toward substitution of light trucks for automobiles in personal transport continues, some of these reductions may be offset by increases in emissions from these vehicles.

But only part of the story is revealed by the impressive opportunities to increase the efficiency of individual end-use devices. Recent investigations at the World Resources Institute (WRI) have demonstrated that policy choices made today and implemented over the next decade can substantially alter the timing and severity of global warming.[10] The WRI analysis used a computer model to evaluate one future scenario based on the continuation of current trends and three alternative policy scenarios. Population and economic growth increased at the same rate in each case. One scenario encouraged a rapid increase in the use of coal and coal-derived synfuels, one incorporated modest policies to reduce emissions growth, and one included aggressive policies to increase efficiency rapidly, expand the use of renewable energy sources, and reduce the rate of tropical deforestation. Table 10 summarizes the key differences between the four scenarios. Figure 7 illustrates the effects of these four scenarios on the timing and extent of global warming. Both the Base Case (or current trends scenario) and the High Emissions Case commit the planet to a climatic change that is more extreme than anything which has occurred in the last million years. Only the fourth case, the Slow Buildup Scenario, slows the rate of emissions growth sufficiently to postpone beyond 2075 an average global warming of 1.5-4.5° C.

The principal conclusion of this analysis is that policy choices will make a difference in the rate and extent of these linked environmental problems. Policy choices made now can either accelerate the onset of severe global warming or limit the rate of those changes in future climate which cannot be avoided. It is extremely important to note that nothing can be done now that will eliminate completely all future global warming and ozone depletion. Due to emissions which have already occurred but whose impact has not yet been fully realized, the composition and behavior of the atmosphere will continue to change. But by implementing policies now to reduce the rate of emissions growth, societies can buy time, limiting the extent of disruption caused by abrupt change and protecting the most vulnerable sectors and geographic areas.

Achieving these reductions in emissions will require a comprehensive approach that encourages improvements in the efficiency of energy use as well as energy supply. Increasing the efficiency of energy use is the fastest, cheapest, safest way to reduce emissions and to encourage economic growth. Policy responses to the greenhouse and ozone depletion problems must recognize the critical role of increasing efficiency, allowing investments in these opportunities to compete directly with investments in improved and expanded energy supply. States and local governments must be given flexibility to achieve reductions in greenhouse gas emissions by the mix of policies that are best suited for their local conditions, with the federal government pre-judging whether those reductions are best improved through improved efficiency or enhanced supply.

Hearings such as this and the recent reports from the World Meteorological Organization, the U.S. National Aeronautics and Space Administration, the BMFT, and others may strike some observers like Chicken Little's announcement that the "The sky is falling." We are indeed asking people to change their behavior in order to reduce the risk of increasing concentrations of some invisible, odorless, colorless gases because we perceive that otherwise there will be an increased risk of substantial disruption to the unseen mechanisms that control regional climates. If ignored, the effects will not be an immediate epidemic with thousands of dead bodies in the street. Rather more importantly, if we ignore the simple inexpensive measures which can reduce the risk of global climate change today, we and our children may pay a much higher price tomorrow as coasts are flooded, agricultural and forest output declines, and human immune systems deteriorate.

Although the specific measures required and the balance of emphases will vary from country to country, any successful national strategy to reduce the risks of future global warming will contain four basic elements. These include (1) policies to increase the efficiency of energy use, squeezing the most useful work and economic value from each pound of fuel or barrel of oil consumed, (2) policies to reduce the releases of the most dangerous chlorofluorocarbons, even beyond the controls contained in the Montreal Protocol on Ozone-Depleting Substances, (3) policies to slow the rate of biotic releases of greenhouse gases, especially those related to tropical deforestation, and (4) policies to shift the mix of fuels consumed away from carbon-intensive fuels derived from coal toward less carbon-intensive sources of energy derived from natural gas, from the high-efficiency use of biomass, from solar, wind, and other renewable energy technologies.

IV. REDUCING EMISSIONS THROUGH INCREASED EFFICIENCY

For the globe as a whole, substantial opportunities exist to reduce dangerous pollutant emissions by increasing the efficiency of energy use. One study (Mintzer, 1987) suggests that economic growth of 2-3% could be sustained and population more than doubled, with no significant increase in global energy use to the year 2075.[11] Another analysis, based on careful case studies of the U.S., Sweden, India, and Brazil, indicates that the introduction of currently available improvements in energy efficiency would allow continued growth in the industrialized countries and an increase of per capita GNP in developing countries, raising them to the per capita standard of Western Europe in the 1970s. This could be accomplished without significantly increasing global energy use beyond the 1980 level of 10 TW per year.[12]

Achieving these goals in the industrialized countries means continuing the present structural shifts in the advanced economies, maintaining a rational regime for energy prices, and investing vigorously in emerging technologies to improve energy efficiency. Important opportunities already exist to increase the efficiency of energy use, even in such energy-conscious countries as Sweden and the Federal Republic of Germany. In the residential sector, for example, new building designs are available which can reduce the heating loads per square meter for U.S. single family dwellings by a factor of ten below the average of the current housing stock. In Sweden, where conservation of energy in buildings has long been considered important, new prefabricated buildings sold by Faluhus, require only one-sixth the energy of the average Swedish housing stock.[13]

Improved performance is also available from competitive designs for domestic appliances. New refrigerators can keep food cold with only 50-75% of the electricity input of the existing stock in the U.S. and Western Europe.[14] These new machines are economically competitive with traditional designs and could easily be refitted to use the safer, less long-lived alternative CFCs. Introduction of these new refrigerators could substantially reduce the need for additional base-load electric power stations in the foreseeable future.

Large savings are also possible from improvements to lighting technology in residential and commercial buildings. New, high-efficiency, compact fluorescent bulbs can deliver the same quantity and quality of light output with only 20-30% of the electricity input required by standard designs. This increased efficiency in the conversion of electricity to light results in a simultaneous decrease in summer cooling loads for buildings. Many of the new lighting systems have payback periods of three years or less, even when the savings from reducing the size of the building's required cooling system is ignored. Advances in the technology of "day-lighting" (i.e., the use of sunlight in lieu of electric light during regular business hours) can also substantially reduce electricity demand for commercial buildings.

In the industrial sector, major improvements are possible through the use of new process controls and the modernization of production technology. Newly developed, solid-state, variable-speed controllers for electric motors can reduce energy demands for industrial prime movers by 30-40%. These devices have payback periods of 1.5-2 years in many applications.

Major improvements are also possible by modernizing industrial technology. The cement industry in the Federal Republic, for example, uses only two-thirds as much energy per ton of output as does the cement industry in the United Kingdom. The paper industry in the U.S. offers a similar advantage over many of its partners in the OECD. By contrast, the U.S. steel industry uses 50% more energy on average to make a ton of crude steel than does the industry in Japan. Licensing, transfer, and adoption of the most advanced, energy-efficient technology in each industrial sector offers the greatest potential for reducing global emissions and spurring economic growth.

One important sectoral trend is likely to spur increased efficiency in many industrialized countries. The transition from crude commodity materials to engineered materials in the advanced countries means that future production will be smaller in physical output than in the past but may be of greater economic value. New high-strength specialty steels and engineered plastics, for example, require less energy to produce but bring much greater financial returns per ton than does production of cheap crude steel or polyethylene. Since most of the basic infrastructure is now in place in OECD countries, the market demand is likely to continue to shift toward these high-value, specialty materials.

In the transportation sector, the most important opportunities for increased efficiency are in road and air transport. New jet engines and composite materials for aircraft construction offer the promise of advanced designs which can fly longer distances while burning half of the fuel per ton-km. Although currently low fuel prices have discouraged the further development of such advanced airplanes, it is certainly feasible to introduce them over the next fifteen years. New car designs such as the Ford Escort, the Plymouth Horizon, the VW Auto 2000, the Renault EVE, and the Volvo LCP 2000 provide adequate proof that cars which use less than 4 liters per 100 km can deliver safe, attractive and efficient transportation for four or five passengers.

By combining these various opportunities, but without depending on any technology which is not now close to commercial availability, it is possible to promote economic growth, maintain European standards of living and simultaneously reduce per capita energy use by fifty percent. Given thirty years for these technologies to penetrate the market, pollution emissions from the Western market economies can be substantially reduced.

The situation of developing countries is equally promising but slightly more complex. Absolute energy demands will continue to grow in these countries as population increases. Per capita demand for fossil fuels and other forms of commercial energy will also continue to grow as industrial modernization proceeds. The challenge facing policy-makers in these countries (and planners in the development assistance community of the industrialized countries) is how to stimulate modernization and growth without repeating all the worst environmental mistakes made by industrialized countries in the past.

The key to achieving a low-emissions, high-growth future for developing countries lies in increasing the efficiency of biomass use. Today, more than half the energy demands of developing countries are met by combustion of various forms of biomass. The inefficient use of these biomass resources is denuding the forests, increasing the risk of soil erosion, and adding to global emissions of trace gases.

The largest single end-use of energy in many developing countries is for cooking.[15] By converting cooking technology from solid to gaseous or liquid fuels, efficiency can easily be improved from current levels of about 10% to levels approaching 60-70% with cheap, engineered cookstoves. Substantial advances (and some significant setbacks) have occurred as a result of programs to achieve these goals in China and in India. Further research and analysis is necessary to increase the success of these programs.

Equally important opportunities exist in the modern sector of developing countries where commercial fuels are already widely used. Many countries, including China, India, Indonesia, Brazil, and Nigeria, are rapidly expanding their industrial base. Because most of these countries are not replacing an out-dated infrastructure but rather are building from scratch, they can skip over many of the now-outdated technologies embedded in the industrial base of the Western and East Bloc economies.

Which technologies are chosen in these countries will substantially affect global emissions rates. Encouraging these countries to invest in the most energy efficient technologies during this period of rapid industrialization will increase competition with the industrialized countries in the short term but will also insure that global emissions are minimized for the long term benefit of all. The national energy strategies promoted by U.S. bilateral aid programs and by the multi-lateral development assistance agencies using U.S. funds will have a prodigious impact on the magnitude and type of future greenhouse gas emissions from developing countries.

Difficult choices will also have to be made by developing countries in the transportation sector. Newly industrializing economies can follow the pattern of the U.S., Western Europe, and Japan, for example, building their passenger transport systems around the automobile. Choosing this path means facing the congestion, pollution, and grime which now plagues Los Angeles, London, Tokyo, and Rome. Alternatively, these countries may choose a path more like Taiwan, basing personal transport on mopeds, motorcycles, and scooters. Or they may follow the Chinese model, keeping cars out of the cities and encouraging the use of bicycles. Which strategy is chosen will ultimately determine the costs, the fuel requirements, and the emissions of the transportation sector.

This combination of conditions now makes it possible to foresee how future growth in trace gas emissions from industrial activities might be slowed down. It will not happen automatically but will require tough political decisions in many countries. Rational consumer behavior will depend on rational pricing strategies. Long-cherished traditions of industrial subsidies will have to be abandoned in many cases in order for consumers to recognize the full cost and scarcity value of energy. Only if they get these signals, can the millions of decentralized decision-makers make optimal choices in the market place.

V. RENEWABLE ENERGY SOURCES

Renewable energy systems, although unlikely to make a major contribution to electricity supply in this century, will continue to be an important component of the energy mix in the next fifty years. Renewables, principally biomass, already supply over half of the energy demand in many developing countries. Though often developed in an unsustainable and environmentally damaging way, these resources will be the basis for rural development for the next twenty years. Engineering improvements to increase the efficiency of biomass use, to protect the availability of crop residues as soil amendments, and to preserve the forests will be essential to sustainable development programs.

Renewable energy systems can also play an important and increasing role in industrialized countries and in the modern sector of developing countries. New combustion technologies (including the development of steam-injected gas turbines) promise opportunities for turning biomass wastes into electricity with conversion efficiencies approaching 40%. Already, biomass-fired, combined heat and power systems are the primary source of new energy in the Northeastern U.S. where the most efficient parts of the paper and pulp industry are located.

Advanced renewable technologies such as photovoltaic and wind systems will make a larger contribution to electricity supply in the near future. These systems are already feasible and require only a small amount of clever engineering to make them competitive with conventional fossil fuel systems. Large central station photovoltaic systems are providing electricity to regional grids in California, Texas, and Sicily, among other places. Wind machines, both large and small are in use in Denmark, California, Australia and the United Kingdom. If sufficient investments in R and D are made in the next decade, these small modular systems could provide 10% of electricity supply on a cost-competitive basis within twenty years. Photovoltaic and wind machines are already cost-competitive with new nuclear power plants in most parts of the U.S..

IV. CONTROLLING FUTURE EMISSIONS AT THE SOURCE

Opportunities are now available to reduce emissions of many radiatively active trace gases at their source. In addition, in some cases controls on gases which are not themselves radiatively active will reduce the damages due to greenhouse gas emissions. Emissions of the most dangerous CFCs, for example, could be substantially reduced by placing a high tax on their production and use. A user fee of $5 per pound, imposed in addition to EPA's proposed system of permits allocating rights to CFC production, would encourage the more efficient use of these compounds, spur recapture and recycling, and stimulate the early introduction of less dangerous substitutes.[16] A bill to implement such a tax is currently being considered for introduction in the House.

Other greenhouse gas emissions may be slightly more difficult to control. A substantial economic penalty imposed on episodes of methane leakage from pipelines, coal mines, and old oil fields would promote the use of technically feasible control measures but would be difficult to monitor and enforce. Potentially as effective and easier to implement would be tougher standards for automobile emissions of carbon monoxide, CO. CO removes the principal sink for methane (hydroxyl radicals, OH) from the atmosphere. By limiting emissions of CO from all sources, including inefficient combustion of biomass, more may be accomplished in the struggle to limit methane buildup than by any measures to control methane emissions directly.

Although technically feasible, it is probably not efficient to attempt to scrub carbon dioxide or nitrous oxide from the atmosphere by post-combustion controls. All known methods require as much or more energy than is generated by the original combustion. Some authors have suggested that CO_2 removal could be made economical in the future but no persuasive demonstration of any such technology has occurred to date.

VII. REDUCING EMISSIONS BY CHANGING THE FUEL MIX

Changing the mix of fuels consumed could substantially alter future emissions rates. Different fuels have dramatically different levels of CO_2 emissions per unit of energy supplied. Table 5 illustrates the CO_2 emissions rates for some common fossil fuels. Burning oil produces about 50% more CO_2 per unit of energy supplied as does burning natural gas. Coal combustion produces about twice as much CO_2 as does natural gas. Synthetic fuels derived from coal leads to even greater rates of CO_2 release. Similarly, N_2O, a principal combustion product from burning coal or fuel oil, is virtually absent from the waste stream when natural gas is burned.

The potential for reducing emissions through fuel switching has lately been enhanced by the development of several advanced combustion technologies. New gas turbine designs, based on military development of new jet engines, promise efficiencies of 40-46% in the conversion of heat to electricity. These small, easy-to-maintain, modular systems may be ideal for expanding electricity supply in heavily congested cities and in rural areas of the Third World. In addition to offering higher efficiency of conversion, these machines are extremely clean-burning, with very low emissions rates for SO_2, NOx, and particulates. They may play an increasingly important role in energy supply in the near future.

VII. THE ROLE OF NUCLEAR POWER

Fission electric systems are likely to play an important role in global energy supply for many years to come. Although the number of nuclear plants in use is not growing rapidly in the U.S., Europe, the Soviet Union, China, or Japan, the plants which are now operating or under construction will continue to produce electricity for 20 - 40 years. Unfortunately, nuclear energy is not likely to substantially displace fossil-fueled electricity production in the timeframe of importance to the greenhouse effect. Commercial nuclear power plants produce substantially less than 10% of the world's electricity. Because they require 5-15 years to build, their contribution can only be increased slowly under the best of circumstances. Very high costs and public perception of major risks in nuclear plant operations have led to a slow down of nuclear construction in all major markets outside of France. As a consequence it is likely that the effect of nuclear energy on the greenhouse effect in the next twenty years will be significantly less than the effect of fuel switching from coal to gas.

VIII. CFCs

The most important reductions in greenhouse gas emissions over the next decade are likely to result from the Montreal Protocol to Control Substances that Deplete the Ozone Layer. Implemented in the EC by a regulation passed last week, this international agreement will reduce the production and use of CFCs by fifty percent from the 1986 levels before the turn of the century. This 50% cut will reduce the annual contribution to global warming by an amount equal to a 15% reduction in CO_2 emissions. If the recent evidence on ozone depletion over the Northern Hemisphere is sufficient to spur further action to control these dangerous chemicals, there will be an immediate concurrent benefit to the greenhouse problem.

VIII. MEASURES TO REDUCE THE RISK OF FUTURE GLOBAL WARMING

In addition to considering these broad general strategies, Congress could implement a small number of cost-effective measures to reduce the rate of growth in greenhouse gas emissions in the near-term. In evaluating measures to reduce the risk of global warming, it is essential that the impacts of each measure on the linked atmospheric problems of stratospheric ozone depletion and acid rain be considered at the same time. The fundamental challenge is to identify specific policy options that can sustain the prospects for economic growth while reducing the long-term risks of environmental damage from the combined effects of these three problems. Three types of measures are available now to address these problems. These include (1) measures to "get the prices right" and improve the efficiency of energy markets, (2) measures to increase the technical efficiency of energy use and reduce emissions at the source, and (3) measures to mitigate the effects of activities which could increase emissions in the future by requiring offsetting reductions. Many of these measures would deliver complementary benefits in other areas of concern to national policy by, for example, increasing our energy security, reducing the damages due to acid rain and the build-up of tropospheric ozone and slowing the depletion of ozone in the stratosphere.

A. Getting the Prices Right

In order to promote efficient allocations of scarce investment capital and to encourage rational behavior by individual consumers, it is critically important in a free market economy to "get the prices right." In the energy sector this means internalizing the full cost of energy mobilization and use into the price of fuels. By incorporating an estimate of the costs of environmental and other externalities into the price of fuels, Congress can improve the efficiency of energy markets. Taxes which reflect at least some of the costs of acid rain, global warming, ozone depletion, and the protection of foreign suppliers will raise energy prices but will help consumers to make more rational tradeoffs between increasing their purchases of fuel supplies and increasing their efficiency of energy use.

One area in which current policies give consumers a distorted and unrealistic picture of the cost of energy supply is the market for gasoline. A tax on gasoline which was equal to two cents per gallon when introduced but increased at a rate of two cents per gallon per month for four years would raise gasoline prices by about one dollar during the next presidential administration. Such a tax, phased in over four years in a slow, steady, and predictable fashion would provide a smooth price path which would stimulate a shift toward more efficient use of energy in the transportation sector. This type of tax could be treated as a user fee, shifting the burden of costs for assuring the security of foreign oil supplies and mitigating the environmental impacts of energy use from the general tax base to the purchasers and users of fuel. It would help both consumers and manufacturers to plan their future car purchases and driving patterns while reducing the emissions that contribute to global warming, ozone non-attainment and acid raid. By the end of the four year period, such a tax would be generating revenues for the federal budget at a rate equivalent to $100 billion per year. These revenues could be divided between our continuing need to reduce the federal deficit and a massive research and development program to modernize the U.S. auto industry and place it once again at the cutting edge of manufacturing technology at the global level.

Another way to "get the prices right" would be to impose a carbon tax that was revenue neutral. Such a tax would be imposed on fossil and biomass energy sources in proportion to their emissions of carbon dioxide or carbon monoxide. The tax would be set to reflect the best current estimates of the relative contribution from each fuel to the linked problems of local air pollution, acid rain, and ozone depletion. Part of the revenues generated by the tax could be rebated to industrial consumers in the form of large tax credits on investments in new technology to improve the efficiency and competitiveness of American industry. Another portion could be rebated to the purchasers of energy-efficient housing through mortgage subsidies for buildings that exceeded federal standards for building energy performance. A portion could be made available through utility rebate programs to occupants of rental housing who agree to institute specific measures to increase their efficiency of energy use.

A third opportunity to improve the efficiency of key market sectors involves the imposition of a large fee, say $5 per pound, on the production and use of the most dangerous CFCs. Such a fee could be used to underwrite a cooperative effort run jointly by industry and EPA to develop safe "drop-in" substitutes for traditional CFCs. The presence of the fee would accelerate the time at which the substitutes would be cost competitive with traditional products and would also stimulate recycling and loss-reduction programs in applications where no safe substitutes exist.

B. Reducing Emissions At the Source

The second class of measures involve reducing emissions of greenhouse gases at their source. Such measures include the introduction of performance-based standards in areas where technologies now exist to improve the efficiency of energy use along with federal efforts to demonstrate the cost effectiveness and feasibility of emerging technologies perceived to be too high a risk for commercial applications.

In the first category, Congress must evaluate the opportunities to extend the National Appliance Energy Efficiency Act to several new areas. The Department of Energy should be directed to evaluate and, if appropriate, introduce standards for key energy end-uses including lighting in commercial buildings, large electric motors in industry, and building shells in residential construction. In addition, if Congress and the members of this Committee are serious about their desire to investigate the potential benefits of alternative fuels for the transportation sector, such programs should require that the new fuel applications generate no greater quantity of greenhouse gases than would have resulted from running the same number of vehicles on conventional gasoline or diesel fuel. In any event, rather than reducing the CAFE standards for such vehicles a priori, Congress should evaluate the appropriateness of combining higher fuel economy standards in the future with incentives to stimulate the introduction of cars and light trucks that do not depend on continuing access to imported oil.

In the second category, Congress should require the Executive Branch to go beyond the energy efficiency research measures identified in the bills recently introduced by Senators Wirth, Johnston, and Stafford. Congress should require that the federal government set a positive example for industry and for residential consumers by demonstrating in all federal buildings, laboratories, and facilities those energy efficiency technologies judged cost-effective by the Secretary of Energy. The large-scale demonstrations that are possible in federal buildings would stimulate production of these technologies and at the same time reduce the emissions of greenhouse gases by the U.S. government itself.

In addition, Congress should now demonstrate its commitment to increasing the efficiency of energy supply as well as energy use by funding a full-scale commercial demonstration of a new electricity-generating technology developed in the United States. This new technology, called steam-injected gas turbines (STIG) offers the promise of an almost 50 percent increase in the conversion efficiency from fuel to electricity. A spin-off from our $400 million per year investment in advanced jet engines for military aircraft, these turbines offer lower costs and much lower emissions of air pollutants than the conventional technologies which they would replace. A joint venture of federal and private funds, modeled on the successful Coolwater Coal Gasification Project, would be an ideal vehicle for bringing this American advance quickly into the competitive international power market.

The Congress should also require all programs that use U.S. government funds for development assistance in Third World countries evaluate the opportunities to improve energy efficiency before approving any funding to increase energy supplies. Both U.S.AID, the World Bank, and other multi-lateral aid agencies should be required to demonstrate that plans to increase energy supply have first considered all available cost-efffective options for increasing energy use and that an evaluation has been completed of contribution of each proposed national energy strategies on future emissions of greenhouse gases, acid precursors and ozone depleters.

C. Offsetting the Impacts

The third set of measures that could slow the rate of growth in greenhouse gas concentrations involve a program to offset future increases in greenhouse gas emissions. Such a program would require a change in the New Source Performance Standards to stipulate that new stationary sources demonstrate no net increase in greenhouse gas emissions. New power plants or industrial facilities could, for example, offset their own future emissions of CO_2 by committing a fixed sum to the planting and maintenance of trees that would take up an equivalent amount of CO_2. Such trees could be planted in urban areas, offering increased shade and local cooling as well as CO_2 removal services. Alternatively, they could be planted on land filter strips to protect rural water supplies, in conjunction with the Conservation Reserve Program. Emissions trading would be allowed so that a plant which could not arrange to plant trees could meet its commitment by investing in efficiency improvements or process changes that would permanently reduce emissions from some other local facility. The administration of such a program need not be cumbersome and might be successfully implemented by local air pollution control districts with technical support from EPA.

IX. CONCLUSIONS

Policy choices made today and implemented over the next several decades can substantially affect the timing and extent of global warming. The most important energy policy options for reducing the rate of global warming include (1) increasing the efficiency of energy use through technical improvements and through changes in pricing policy to eliminate subsidies, (2) fuel-switching to less carbon-intensive fuels and the development of renewable technologies, and (3) reducing the use of the most dangerous CFCs. A wide range of cost-effective measures are available today to reduce the U.S. contribution to future global warming. Implementation of specific measures to carry out these broad policy options can postpone for as much as sixty years the global commitment to a warming equal to the effect of doubling the pre-industrial concentration of CO_2 alone.

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TABLE 2

Potentially Important Economic Impacts Of Global Warming

- Coastal Flooding and Salt Water Intrusion
- Changes in Availability of Irrigation Water
- Reduced Forest and Crop Yields
- Increases in Peak Electric Power Demand
- Adverse Impacts on Human Health

TABLE 1

Direct Effects Of Global Warming

- Sea Level Rise
- Changes in Winds and Ocean Currents
- Changes in Precipitation and Water Resources
- Changes in the Frequency of Extreme Events

Table 3

KEY GREENHOUSE GASES:

Present concentrations in air,
Rates of increase, and
Pre-industrial era concentrations

Gas	Concentration In Air Pre-Industrial	1980	Present Rate of Increase (per year)
Carbon dioxide, (CO_2)	275 ppm	346 ppm	1.4 ppm (0.4%)
Methane, (CH_4)	0.75 ppm	1.65 ppm	17 ppb (1%)
Fluorocarbon-12, (CCl_2F_2)	Zero	400 ppt	19 ppt (5%)
Fluorocarbon-11, (CCl_3F)	Zero	230 ppt	11 ppt (5%)
Nitrous Oxide, (N_2O)	280 ppb	305 ppb	0.6 ppb (0.2%)
Ozone, Tropospheric (O_3)	15 ppb?	35 ppb	0.3 ppb? (1%) Northern Hemisphere Only
Other Fluorocarbons	Zero		(5 to 15%)

ppm = parts per million
ppb = parts per billion
ppt = parts per trillion

TABLE 4

Historical Distribution Of CO_2 Emissions From Fossil Fuels

(Millions of Tons of Carbon)

	YEAR			
COUNTRY	1960	1970	1980	1985
United States	783	1149	1249	1186
Western Europe	523	779	853	780
Japan	60	195	243	244
Soviet Union	389	613	871	958
China	214	211	395	508
Other Developing Countries	188	336	658	819

TABLE 5

Carbon Dioxide Emissions From Direct Combustion of Various Fuels

Fuel	CO_2 Emission Rate (kg C/10^9J)	Ratio Relative to Methane
Methane	13.5	1
Ethane	15.5	1.15
Propane	16.3	1.21
Butane	16.8	1.24
Gasoline	18.9	1.40
Diesel Oil	19.7	1.46
No. 6 Fuel Oil	20.0	1.48
Bituminous Coal	23.8	1.73
Subbituminous Coal	25.3	1.87

TABLE 6 CO_2 Emission Rates for Synthetic Fuels

Fuel	CO_2 Emission Rate (kg C/10^9J)	Ratio Relative to Methane
Shale Oil		
In situ 28 gal/ton shale	48	3.5
High temperature 25 gal/ton shale	66	4.9
High temperature 10 gal/ton shale	104	7.7
Liquids from Coal		
Sasol technology; Eastern coal	42	3.1
Exxon donor solvent; Eastern coal	39	2.9
Gasoline from methanol from coal	51	3.8
High-Btu Gas from Coal		
Lurgi	41	3.0
Hygas	40	3.0
Methanol		
From natural gas	21	1.5
From coal	36-44	2.7-3.2

TABLE 7

CARBON DIOXIDE EMISSIONS IN THE UNITED STATES

AS A SOURCE OF FOSSIL FUEL ENERGY		AS A SOURCE OF CARBON DIOXIDE
25%	NATURAL GAS	18%
49%	OIL	49%
26%	COAL	33%

TABLE 8

CARBON DIOXIDE EMISSIONS IN THE U.S.
USERS AND FUELS

Residential/ Commercial	Coal	0.3%	
	Oil	3.9%	
	NG	7.6%	
			11.8%
Industry	Coal	5.0%	
	NG	7.0%	
	Oil	12.0%	
			24.0%
Transportation	NG	0.5%	
	Oil	30.7%	
			31.2%
Electric Utilities	Oil	2.1%	
	NG	2.9%	
	Coal	28.0%	
			33.0%
TOTAL			100.0%

TABLE 9

CO_2 Emissions From Fossil Fuels, 1971-86

(Millions of Tons of Carbon)

Year	CO_2 From Burning Gas Fuel	CO_2 From Burning Petroleum	CO_2 From Burning Coal	CO_2 From Flaring Gas	Total CO_2 Emissions From Fossil Fuels
1971	553	1946	1594	90	4183
1972	582	2056	1612	95	4345
1973	608	2240	1622	112	4582
1974	616	2245	1620	107	4588
1975	621	2132	1715	96	4564
1976	645	2313	1754	110	4822
1977	646	2390	1812	108	4956
1978	673	2384	1828	106	4991
1979	715	2538	1899	74	5226
1980	721	2411	1922	78	5132
1981	731	2276	1930	58	4995
1982	725	2191	1986	56	4958
1983	733	2170	1992	52	4947
1984	786	2219	2080	52	5137
1985	807	2189	2181	52	5229
1986	825	2283	2209	52	5369

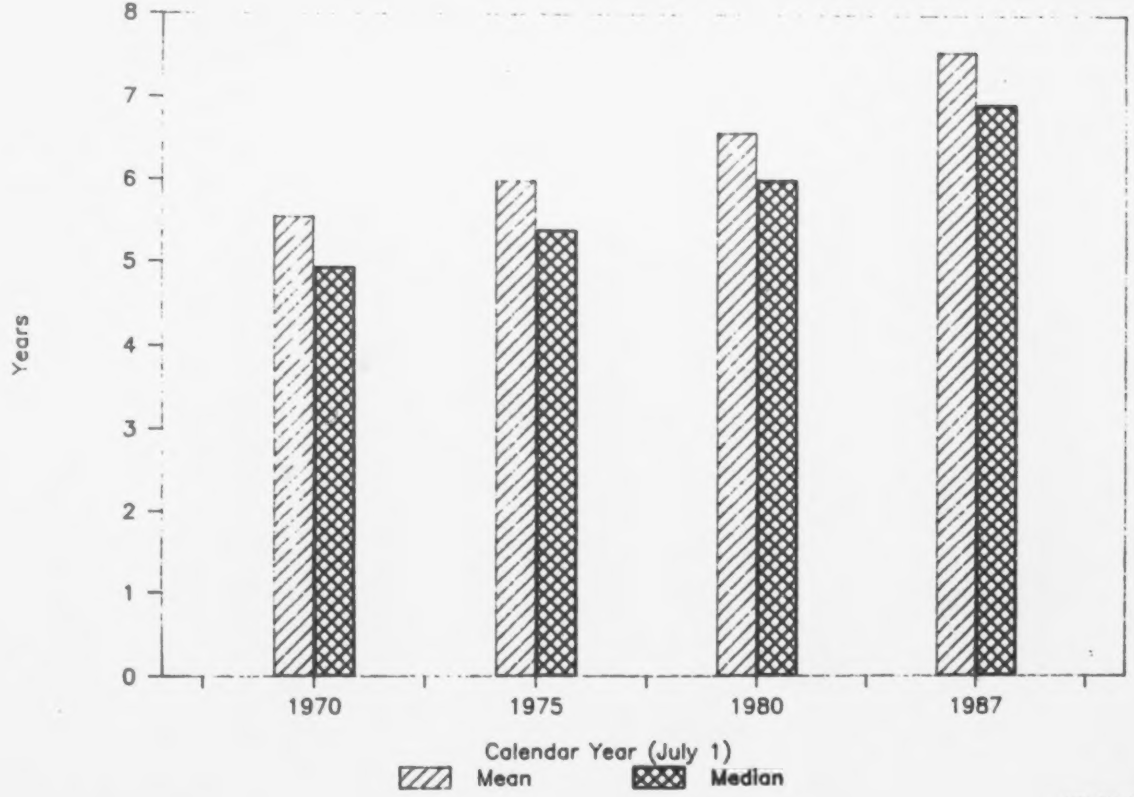
TABLE 10

Energy Policies in the WRI Scenarios

Scenario	Related Energy Model Parameter Value	Warming Commitment (Degrees Centigrade)
Base Case		
• "Business-As-Usual," the inertial model of growth and change in the world energy industry • No policies to slow carbon dioxide emissions • Minimal stimulus to improve end-use efficiency • Modest stimulus for synfuels development • Minimal stimulus for development of solar energy systems • No policy to limit tropical deforestation or to encourage reforestation • Minimal environmental costs included in price of energy	(Rate of change = 0.8% per year) (Final Price = $3.15-$4.25 per GJ in 2005) (Final Price = $16.50 per GJ in 2025) ($0.30 per GJ for coal; $1.00 per GJ for synfuels)	1980: 0.5 - 1.5 2000: 0.9 - 2.6 2030: 1.6 - 4.7 2075: 2.9 - 8.6
High Emissions		
• Accelerated growth in energy use is encouraged • No policies to slow carbon dioxide emissions • No stimulus to improve end-use efficiency • Modest stimulus for synfuels development • No stimulus for development of solar energy systems • Rapid deforestation and conversion of marginal lands to agriculture • Token environmental costs included in price of energy	(Rate of change = 0.2% per year) (Rate of Improvement = 0.75% per year) (Final Price = $2.75-$3.50 per GJ in 1995) (Final Price = $20.00 per GJ in 2040) ($0.15 per GJ for coal; $0.50 per GJ for synfuels)	1980: 0.5 - 1.5 2000: 1.0 - 2.9 2030: 2.3 - 7.0 2075: 5.3 - 16.0
Modest Policies		
• Strong stimulus for improved end-use efficiency • Modest stimulus for solar energy • Substantial efforts at tropical reforestation and ecosystem protection; more intensive rather than extensive agriculture encouraged • Substantial environmental costs imposed on energy prices to discourage solid fuel use and encourage fuel-switching	(Rate of change = 1.0% per year) (Final Price = $15.00 per GJ in 2025) ($0.60 per GJ for coal; $1.50 per GJ for synfuels)	1980: 0.5 - 1.5 2000: 1.0 - 2.9 2030: 2.3 - 7.0 2075: 5.3 - 16.0
Slow Build-up		
• Strong emphasis placed on improving energy efficiency • Rapid introduction of solar energy encouraged • Major global commitment to reforestation and ecosystem protection • High environmental costs imposed on energy prices to discourage solid fuel use and encourage fuel-switching	(Rate of improvement = 1.5% per year) (Final Price - $12.00 per GJ in 2000) ($1.20 per GJ for coal; $3.00 per GJ for synfuels)	1980: 0.5 - 1.5 2000: 0.8 - 2.5 2030: 1.4 - 4.2 2075: 2.3 - 7.0

FIGURE 1

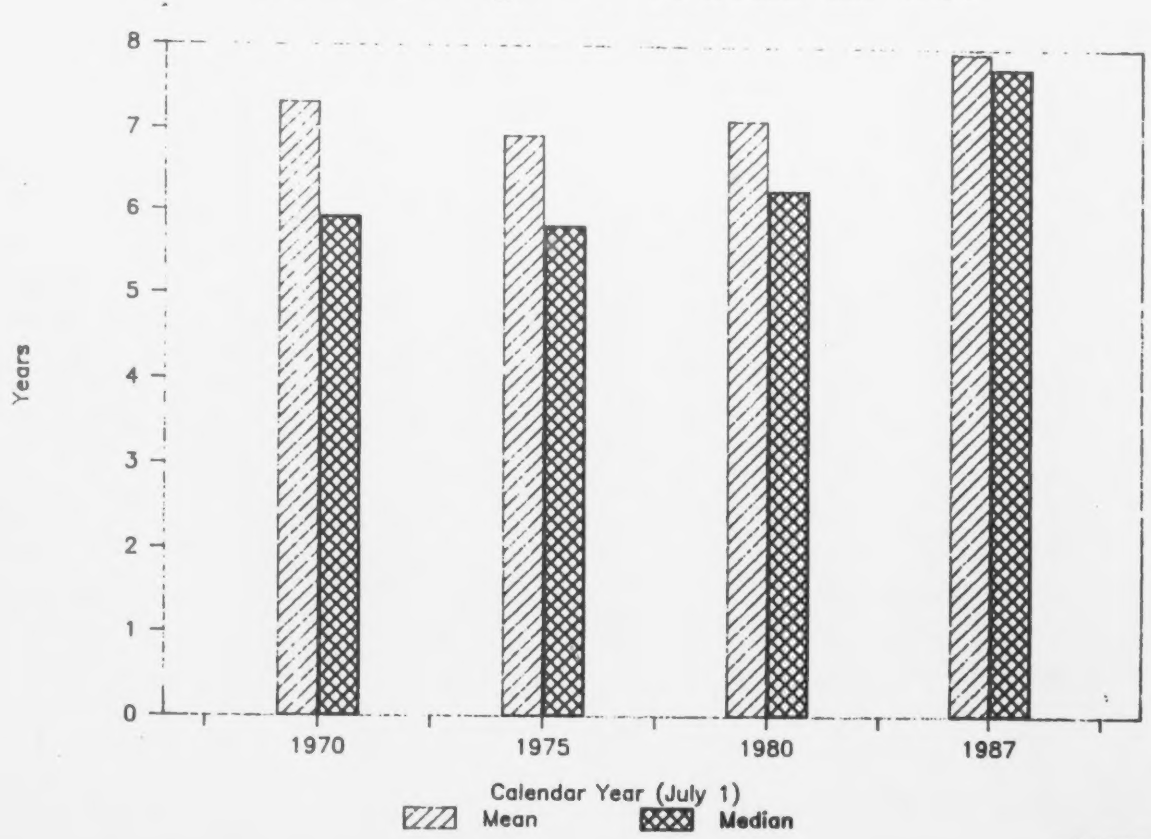
Average Age Of Passenger Cars In Use



WALSH/9-12-88

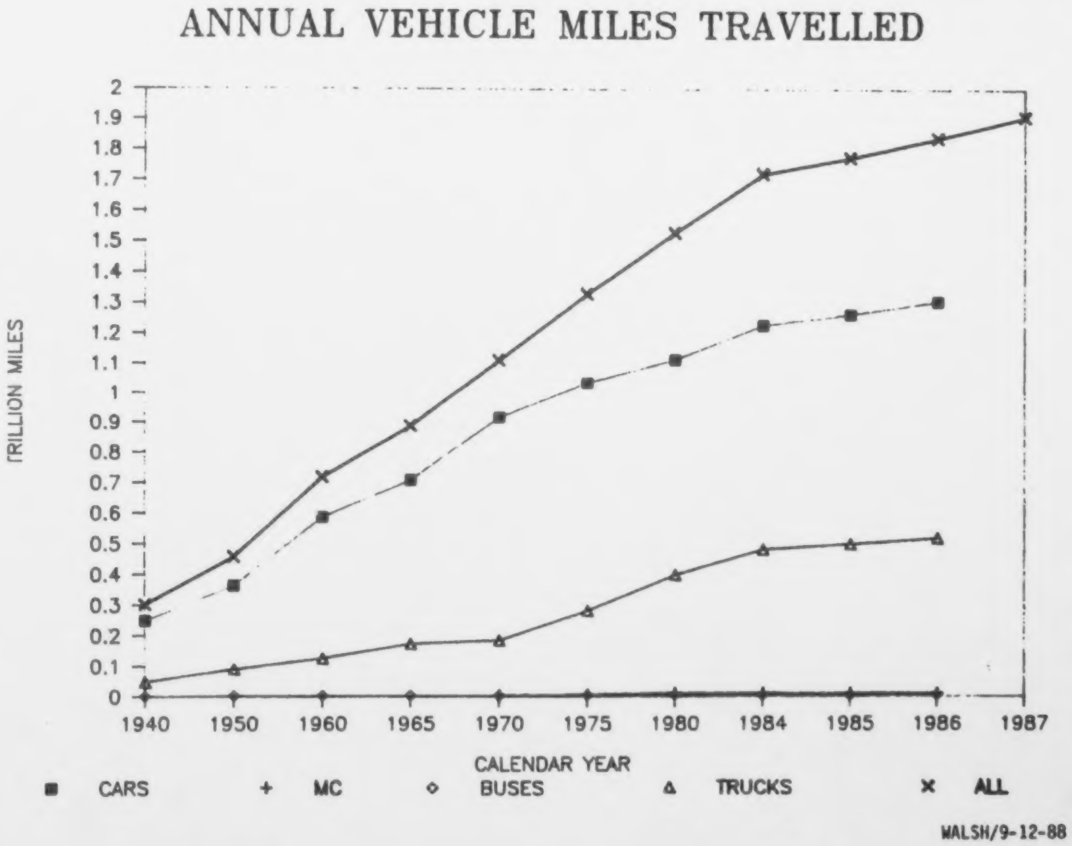
Figure 2

Average Age Of Trucks In Use



WALSH/9-12-88

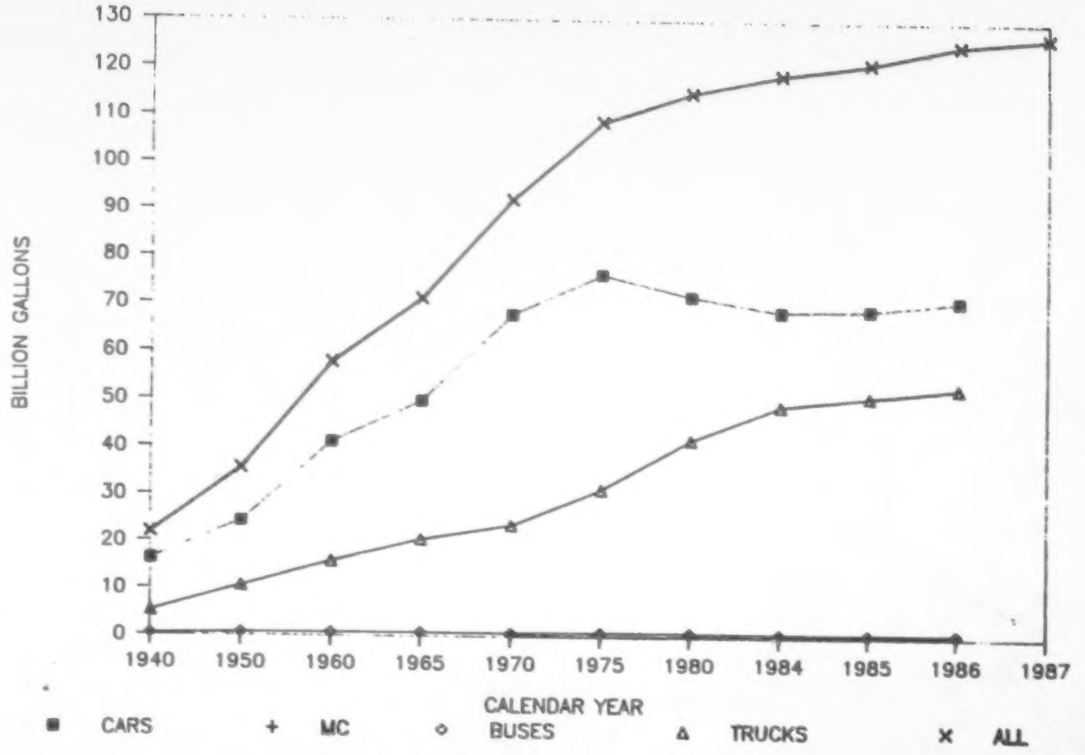
FIGURE 3



WALSH/9-12-88

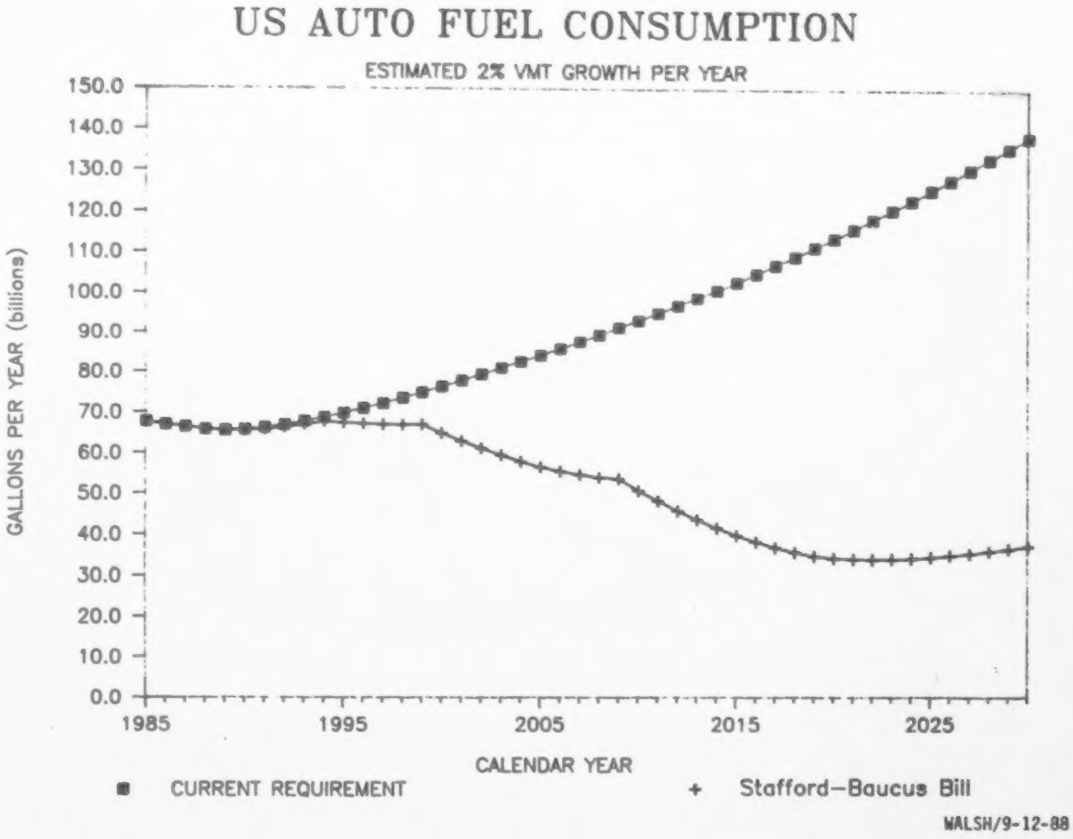
Figure 4

ANNUAL FUEL CONSUMED



WALSH/9-12-88

FIGURE 5


US AUTO FUEL CONSUMPTION
ESTIMATED 2% VMT GROWTH PER YEAR
GALLONS PER YEAR (billions)
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
1985
1995
2005
2015
2025
CALENDAR YEAR
■ CURRENT REQUIREMENT
+ Stafford–Baucus Bill
WALSH/9-12-88

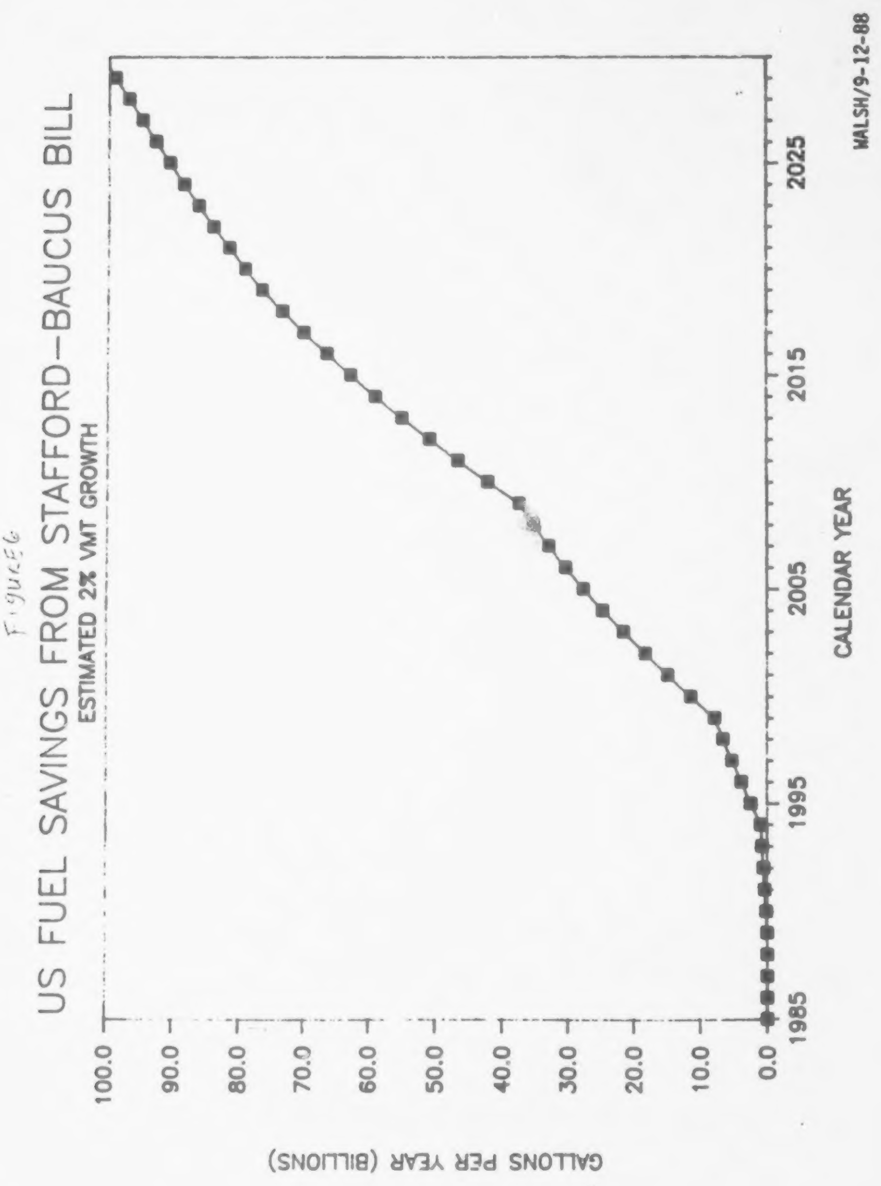


Figure 6

US FUEL SAVINGS FROM STAFFORD-BAUCUS BILL

ESTIMATED 2% VMT GROWTH

AMERICAN FORESTRY ASSOCIATION
balanced forest use

Founded 1875

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September 29, 1988

Statement for the record

of

R. Neil Sampson
Executive Vice President
American Forestry Association

to the

Subcommittee on Hazardous Wastes and Toxic Substances
Senate Committee on Environment and Public Works

Mr. Chairman. Members of the Committee.

I am Neil Sampson, Executive Vice President of the American Forestry Association. The American Forestry Association is the nation's oldest citizen's conservation organization, with a national membership dedicated to the improvement of America's trees and forests.

I commend you for holding hearings on the global warming issue. This is perhaps the most important environmental issue to face this nation in many years, and you can be assured of the active and enthusiastic support of our organization as the Congress addresses it.

My purpose is to ask the Committee to consider an element that we feel would strengthen and improve any legislative response to global warming. That element would consist of a title creating a new community grant program to cities and towns -- an incentive to help encourage and support aggressive new energy conservation elements to their urban forestry programs.

The evidence pointing toward the need for such a title is fairly straight-forward. Our urban forests are dying. A 1987 survey done by the American Forestry Association indicated that, on average, 4 trees are dying or being removed for every new one planted today. The shady, pleasant communities created by our forefathers are becoming, instead, urban "heat islands" where average temperatures 3 to 10 degrees higher than the surrounding countryside are common.

The National Citizens Organization For Trees, Forests, and Forestry

Research has shown that breaking that "heat island" effect can be one way to reduce energy consumption -- particularly peak-load energy consumption associated with air conditioning during peak periods. Studies at the Lawrence Berkeley Laboratory of the University of California at Berkeley, and reported just last month at the ACEEE Summer Study on Energy Efficiency in Buildings demonstrate that the most cost-effective way to attack the urban heat problem is to improve the density and health of the urban forest.

Their research shows that just 3 trees around the south and west sides of a house can reduce air conditioning bills by 10 to 50 percent, depending on the conditions in the community. We estimate that, in total, there are somewhere on the order of 100 million available "tree spaces" in urban communities where new trees are urgently needed. Planting those trees could result in a savings of one-half quad of energy, and as much as 18 million tons of carbon dioxide production, each year.

Our work with the National Urban Forest Council convinces us that mobilizing American citizens to improve their community's environment is a relatively easy task, when you work one community at a time. What's difficult is to mount a massive national effort. We at AFA are committed to carrying out the most effective national public education campaign on this issue that our resources will allow. We think that will help. But it won't be enough.

In addition, there needs to be some economic incentives, to help capture the attention of civic leaders and local government officials. If they are convinced that their local efforts are part of a national battle to reduce carbon dioxide emissions, and if they are shown that the federal government is willing to help them in that effort, they will act.

We are not so naive as to think that planting urban trees is going to solve the carbon dioxide problem, or turn the global warming trend around. We do think, however, that this program offers one very attractive step in the right direction. It is attractive for several reasons. It is relatively low-cost, and very cost-effective. It can be started instantly -- today, if we wish. The technology is at hand.

This idea is politically powerful, because it empowers people and calls them to individual and community action on a critical global issue. It helps demonstrate that the fight for a better environment is everybody's fight, and that it can start with each of us, in our daily lives, where we live and work. People who view the global warming issue in that light, and who have done their part to heal the environment, are going to expect similar performance from their business and political leaders.

For these reasons, we urge you to consider adding a community forestry incentives program to any legislative response that you should develop, such as S. 2667, the National Energy Policy Act, or S. 2663, the Global Environmental Protection Act. We stand ready to assist you in any way possible in its drafting and passage.

I would like to briefly touch three other aspects of the very close connection between forestry and the greenhouse effect. Forest Service data shows that public and private forestlands in this country have a tremendous potential for improved tree growth. They estimate that forest owners have economically feasible opportunities (meaning those that will return a 4 percent annual return on investment) that could increase annual forest growth by up to 17 million cubic feet per year. If those investments were made, the carbon dioxide trapped and stored in that additional wood growth would add up to about one-third of what we now produce from the burning of fossil fuels in this country. In other words, improved forest management could significantly accelerate the biological "downdraft" that removes carbon dioxide from the atmosphere. Clearly, there would be other environmental and economic benefits as well.

But forest management -- and, particularly, increasing forest growth rates -- is not going to be made easier if climate changes are too rapid or moisture regimes change too much. Forest managers must make investments of 30 to 100 years, betting on growing conditions that are somewhat similar to those of the past. That may no longer be a good bet. If it isn't, and they face significant departures from historical conditions, then they need more information, and they need it fast. If they are faced with planting different species on some sites, or perhaps with abandoning other sites, because of climatic change, the people making today's decisions need to know those facts as soon as possible.

All of this argues for an accelerated research program, both in terms of understanding and quantifying the global warming trend, and in determining its impact on forests and forest management. We will make that argument more directly when it comes time to testify on the Forest Service's research budget, but we wanted to make sure it was recognized in connection with the bill before you today.

Finally, a word about tropical deforestation. Our Association is appalled at what is happening to tropical forests, and the November-December issue of our magazine, American Forests, will be devoted almost entirely to that situation, and to its connection with international climate, wildlife, species preservation, and economic issues.

We are particularly repelled by the projects that slash and burn tropical forests in an attempt to convert those lands to long-term agriculture. The impact of those huge conversions is clearly a significant factor in today's carbon dioxide imbalance, largely because the wood is burned and what little organic matter remains in the soil is subject to almost-immediate oxidation. We applaud the fact that S. 2667 would bring additional federal policy attention to that situation, and we hope that the combined efforts of several such policy initiatives will assure that, in the very near future, we will be able to say with confidence that the United States is no longer underwriting any such project and is, instead, providing assistance to those nations to help them meet their very real needs for economic growth while, at the same time, reforesting those areas that cannot come back effectively from their current condition. Its a large challenge, but one that needs to be faced.

Global warming is a symptom of an environment out of balance, largely because of human activities. Now that we understand the tremendous damages this imbalance can inflict on people everywhere, this Nation must act. If we are to act wisely, and exert the international leadership required, we must act together -- on many fronts at once, and with as many of our citizens joining into the action as possible.

We are convinced that the global warming threat brings the most visceral, compelling, moving argument for forestry action -- both urban and rural, both public and private -- since the massive rape of forests in the last century led to the pioneering conservation thrust of the Teddy Roosevelt - Gifford Pinchot era.

We don't believe, and wouldn't propose, that better forests will solve the global warming crisis. But we do believe, very strongly, that the improvement of trees and forests is one essential element in the all-out campaign that we must mount to right the environmental wrongs of the past and begin to heal the earth.

We appreciate the chance to express our views, and would be happy to answer questions, or to provide assistance in any way the Committee would desire.

NATIONAL ACADEMY OF SCIENCES

2101 Constitution Avenue Washington, D.C. 20418

OFFICE OF THE PRESIDENT

September 13, 1988

The Honorable Max Baucus
Committee on Environment and
Public Works
458 Dirksen Senate Office Building
Washington, D.C. 20510

Dear Senator Baucus:

I wish to commend you and your colleagues for scheduling hearings on the critical issue of global climate change and for launching the discussion of policy responses with your proposed legislation.

My own view is that there is a strong basis for concern about the depletion of stratospheric ozone, most evident in the Antarctic and attributed to chlorofluorocarbons; the increasing levels of greenhouse gases such as carbon dioxide; continuing deforestation and the resulting addition of carbon dioxide to the atmosphere; and regional air pollution linked to acid precipitation. We may be conducting an irreversible experiment with our planet, in that man has become an agent for climatic and environmental change possibly rivalling natural forces. The consequences could be profound and unprecedented.

In the case of the greenhouse effect, combining what we understand of natural processes and projections of population growth, economic development, and other social factors, we predict that by the year 2050, the increase in greenhouse gases will be roughly equivalent to a doubling of the pre-industrial level of carbon dioxide. That translates into increasing global temperatures and, just as significantly, a rate of climate change about 100 times faster than the average rate of change since the last glacial period.

As you recognize, these phenomena are fraught with uncertainties -- about the relation of climate changes and changes in sea levels and rainfall patterns, for example -- but they could have major economic, social and political consequences. In these circumstances, I believe that prudence requires us to take certain actions now. These include, at a minimum, increased global monitoring, renewed R&D efforts in energy conservation and alternative energy development, research to adapt crops to different climate conditions, and measures to contain the devastation of tropical forests.

For the longer term, we must develop flexible and resilient policies on energy use and demand, pollution, agricultural land use, water resources, and coastal development that will help us adapt to a spectrum of possible climatic conditions.

Developing and gaining acceptance for such policies will not be simple; but I believe that we can meet the challenge through the increasing strength of our scientific understanding of global environmental change and through careful consideration of measured responses by Congress, the administration, and other governments at the highest levels. This issue should be on the agendas of the Economic Summits and other meetings of heads of state.

The Academies are eager to contribute to these deliberations. We are preparing a white paper on climatic change to inform the incoming administration, and we are responding to requests in recent legislation for studies of policy options and strategies for developing alternative energy sources. We look forward to an early opportunity to present our conclusions to your committee.

Yours sincerely,

Frank Press

Frank Press
President